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Maine Agricultural Experiment Station

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BULLETIN 219 OCTOBER 1913

COMPARATIVE STUDIES OF CERTAIN DISEASE PRODUCING SPECIES OF FUSARIUM

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BULLETIN No. 219.

COMPARATIVE STUDIES OF CERTAIN DISEASE PRODUCING SPECIES OF FUSARIUM.

Charles E. Lewis.

The genus, Fusarium, contains a very large number of species. The descriptions of many of these are very incomplete, frequently, being based on the examination of a single collection of material. Since cultural studies of certain species have shown that the same fungus may show quite different characteristics when the conditions for growth are changed, the validity of many of the species is called in question. For example, in certain species of Fusarium starting with material from a colony from a single spore it would be possible by growing the fungus on different culture media to bring about differences as great as those which have been used in the separation of species. In many cases, in those forms which are parasitic, the occurrence of a Fusarium on different though closely related hosts has been considered sufficient reason by certain writers for describing the fungus on each as a different species. A good illustration of this is found in the fungus causing the scab of a number of cereals. It was described under a different name on each host but the work of Selby and Manns * has shown that the same fungus causes the disease in several hosts. This was determined by growing the fungus from each host in culture, comparing the cultures and making cross inoculations.

It is probable that careful and extended cultural studies together with inoculation experiments will greatly reduce the number of species. One great difficulty lies in the incomplete descriptions which make it impossible in many cases to deter-

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* Selby, A. D., and Manns, T. F., Ohio Expt. Sta., Bul. 203, p. 231, 1909.

mine whether the fungus which is being studied has been described. In some cases, an investigator after making an extended study of a species of this genus has described it as new because of the impossibility of placing it among those already described and at the same time has pointed out the possibility that it may have been incompletely described under another name. These new species however in which the descriptions take into consideration the characters of the fungus under different conditions of growth make it possible to determine with a considerable degree of certainty whether a fungus which is being studied agrees with the description or not. In some cases the account of the study of a species may become so extended as to make it difficult for the reader to pick out the most important points. It would be very desirable if each person who works with a species of Fusarium would either keep the fungus in culture or would send a culture to a laboratory which would keep it growing so that others who desire to do so may obtain it for comparison. In the study of this genus. the comparison of species grown side by side under the same conditions is very desirable.

Interest in the genus has increased with the knowledge that a number of very important plant diseases are caused by species of Fusarium. There can be little question that with further study it will be found that some of them which have been regarded as saprophytes are parasites which cause a considerable amount of damage to living plants. Owing to the difficulty in determining the species and the amount of cross inoculation work which should be done in order to determine the extent of the parasitism of each, a large amount of study is necessary in order to come to definite knowledge in regard to the characteristics of each and its importance as a cause of disease.

On account of the lack of knowledge of the diseases caused by species of Fusarium in Maine, although such fungi were frequently encountered in the examination of diseased plant tissues, it has seemed desirable to make some study of the forms isolated from different hosts and to test their pathogenicity by means of inoculation experiments.

In the study of the fungi responsible for the decay of Maine apples, two species of Fusarium were isolated from decaying fruit in 1908. These fungi were grown in pure culture and were tested to determine the extent to which they would cause decay of ripe apples. It was found that each of these caused rot and at about the same rate as some of the well known apple decay fungi which were being studied at the same time. Not much work was done with these fungi until the next summer when green apples were inoculated and a decay was produced in each case. The decay of the green fruit was regarded as better proof that they are parasites than the rot of the ripe fruit because a number of fungi are able to grow on ripe apples which cannot attack green fruit. The organisms were re-isolated in pure culture in a sufficient number of cases to make sure that the decay was caused by the fungus with which the apple was inoculated. These strains were designated Fusarium I and Fusarium II from apple, or F I and F II. (See list on p. 222).

In looking up the subject, no reference was found to any report of a Fusarium decay of apples in America but it was found that Osterwalder * had studied and described such a decay in Europe. The fungus which causes the rot enters the apples through the blossom end and grows down into the cavity around the seeds spreading from here into the surrounding tissues. The tissues become light brown in color and bitter to the taste.

Osterwalder studied the fungus not only as it occurs in nature but in culture on a number of media and describes its characteristics in some detail. He regarded it as a new species, *F. putrefaciens.* Inoculations were made on both apples and pears and it was found that when the fungus was placed in wounds it caused decay, but attempts to produce infection through the uninjured epidermis resulted in failure. Only one such apple rotted and this rot was caused by another fungus, *Cephalothecium roseum* Cda.

The review of this article in Experiment Station Record, Vol. XVII, p. 50, says: "The author claims that the fungus is identical with that reported by Eustace as *Cephalothecium roseum* which causes a rot of apples. He agrees with Eustace † and others on the ability of this fungus to cause a rotting of the fruits in this way refuting the claims of a number of European investigators." The writer did not find anything in Osterwalder's account to indicate that he regarded *F. putrefaciens* and *C. roseum* as identical. In connection with the fact that *C. roseum* was isolated from an apple which decayed after inoculation with the Fusarium, the status of *C. roseum* as an apple decay is discussed but this is followed in the next paragraph by a discussion of the species of Fusarium which have been described from apple fruit with the result that it was decided that the Fusarium which had been studied should be regarded as a new species, *F. putrefaciens.*

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* Osterwalder, A. Ueber eine bisher unbekannte Art der Kernobstfäule verursacht durch *Fusarium putrefaciens* Nov. spec. Centrabl. Bakt. Zweite Abt. 13, 207-213; 330-338, 1904.

† Eustace, H. J., N. Y., State Sta. Bul. 227, 1902.

Owing to the similarity of the decay found in Maine to that described by Osterwalder and the fact that one of the fungi, F I, found here seemed to agree rather closely with the description of *F. putrefaciens,* a culture was secured from Dr. Osterwalder in July, 1909, and has been grown on the same media since that time for comparison with the species isolated in Maine:* Some slight differences have been observed in cultural characteristics chiefly in the red color of the mycelium. The red color is much brighter in the Maine form than in the European on the same medium under the same conditions. Inoculations of apples showed that *F. putrefaciens* and the similar form from Maine caused decay of fruit at so nearly the same rate that one could not be regarded as a more active cause of decay than the other.

Each year since 1908 a considerable number of apples have been found in which a Fusarium was causing decay. The Fusarium rot is easily distinguished from the other common apple rots in its later stages when the mycelium has grown out through the lenticels and has partially covered the surface of the apple. This aerial mycelium is white at first but soon takes on some red and yellow color. In the early stages it is not always possible to distinguish this rot from those caused by other fungi. The decayed tissues are light brown in color and are bitter to the taste. The skin of the apple is darker in color than in the case of apples rotted by Penicillium but not so dark as with Sphaeropsis or Glomerella.

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* See foot-note p. 254.

Fusarium may attack the apple fruit in 2 ways. Both of the species isolated in 1908 were first found growing in wounds on the surface of the fruits. Associated with them were other fungi, part of which proved to be parasites and part saprophytes when inoculations were made into apple fruits. Later each of the two species was found growing in the cavity around the seeds and spreading into the surrounding tissues to cause decay just as Osterwalder described for *F. putrefaciens*. In such cases the fungus enters the seed cavities through the canal which extends down from the blossom end and which does not become closed in some varieties. Apples which appear sound may show when cut open a growth of mycelium around the seeds. If such apples are kept in cold storage, the fungus cannot grow but when the apples are subjected to a higher temperature for several days the mycelium spreads into the surrounding tissues causing the loss of the fruit. Either F I or F II may be responsible for such decay. As will be shown later Fusarium forms from a number of sources are capable of causing rot of apple fruits upon inoculation but these two species are the only ones which have been found to occur on the fruit in nature to such an extent as to cause much loss. A third form was isolated from a decaying apple in 1909 but has not been found again.

While these species of Fusarium are to be regarded as causes of storage rot of ripe apples, that part of the infection which takes place through the blossom end probably occurs in most cases before the apples are placed in storage. In some cases, infection through wounds may also occur before harvesting as in apples injured by insects or by hail. Wounds caused by rough handling also serve as a place of entrance for these as for other rot fungi. In a few cases green apples on the tree showing growth of Fusarium on wounded places have been found. Fig. 105 shows the appearance of such an apple. The fungus was isolated from this apple and has been grown for more than two years in comparison with Fusarium I with the result that the two strains are regarded as belonging to the same species. This has been isolated a number of times from apples. In one lot of Milden apples which were under observation in 1912 mycelium of a Fusarium was found in the core in many cases. Later an attempt was made to isolate the fungus from each of 20 of the apples which were either partially or wholly decayed and in which the rot appeared to be caused by a species of Fusarium. Small pieces of decayed tissue were removed from the inner part of each apple and placed in plates containing 10 c. c. of prune agar. From 15 of the 20 apples pure cultures of Fusarium were found. The plates from the other apples showed a growth of Fusarium but there was also a growth of other fungi. Transfers were made from the plates to tubes and the growth on various media agreed very closely with that of F I. Tests were made of ten of these strains which proved that each was capable of producing decay in apples of three varieties, Baldwin, Mann and Bellflower. One strain was used in making inoculations of apples of each of the following varieties: Rhode Island Greening, Baldwin, Gano and Northern Spy, with the result that decay was produced in all.

F I grows readily on a large number of the culture media which are in common use in growing fungi for study. On sterilized bean pods, potato, carrot, turnip, and beet cylinders in tubes, a rather large amount of white aerial mycelium is produced within 3 to 5 days after transfers are made if the cultures are kept at a favorable temperature for growth. Usually within 5 days, red color begins to appear in the mycelium near the culture medium. In a few days, this covers the whole slant in vegetable cylinders and becomes a very bright red. When the cultures become older there is some yellowish and greenish yellow mycelium. This was especially noticeable on beet cylinder cultures three weeks old.

In cultures grown under favorable conditions, great quantities of spores are produced. In young cultures spores of many shapes and sizes are found. These include as one extreme one-celled spores, about 8 microns in length, which have usually been designated microconidia and as the other large, 5-septate spores, 52 microns in length, which have been called macroconidia. In older cultures of this fungus when the conditions of growth are favorable to their development, orange colored masses of spores are produced. The spores found in these sporodochia are more uniform in shape and size than those found in the young cultures, as shown in Figs. 86, 87 and 88.

Appel and Wollenweber * regard these as normal spores while the spores of various shapes and sizes are regarded as abnormal. They base much of their classification of species on the shape and size of the spores produced in sporodochia. According to their account the sporodochia are produced readily when fully developed normal spores are transferred to sterilized plant stems in tubes. If on the other hand, mycelium is transferred there is growth of much more mycelium and the sporodochia do not develop so readily, if at all. The writer is able to confirm this from the results of work with certain strains of this species from apple. Sporodochia appeared in the cultures and when transfers were made from these to potato cylinders the whole slant became covered with an orange colored mass of spores, after a few days' growth. On the same date transfers were made using material from the aerial mycelium from the same tube with the results that in the cultures from this source mycelium began to develop at once giving a growth so different in character from that which developed from spores that the two sets of cultures might be classified as belonging to different species or even genera if the classification was based on these cultures alone without regard to their origin.

F II from apple agrees in certain characteristics with F I. On the same culture media the two fungi give a somewhat similar appearance. Both produce an abundance of white aerial mycelium although the amount is slightly greater in F II. The red color is the same in the two forms and differs from that in the cultures of *F. putrefaciens*, F XII, sent to me by Osterwalder when all are grown on the same medium. In *F. putrefaciens* the red color is not so bright but seems dull in comparison and it extends to the aerial mycelium to a greater extent than in F I and F II so that there is not so much contrast between the white aerial mycelium and the red color next to the medium. This difference has been noted many times.

F II can be readily distinguished from F I by microscopic examination of the spores. In the former, an additional type of spore is found. These spores are obovate to pyriform in shape, the obovate spores usually being one-celled and pyriform spores

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* Appel, O., and Wollenweber, H. W. Grundlagen einer Monographie der Gattung Fusarium (Link). Arbeiten aus der Kaiserlichen Anstalt für Land-und Forstwirtschaft. Band VIII; Heft I, 1910.

2-celled. Very frequently in cultures 2 to 4 weeks old the spores of the obovate type in this fungus are about equal in number to those of the septate Fusarium type while in the same cultures when a few days old a much smaller proportion of obovate spores is found. This is especially striking when the spores are sown in prune agar plates. The young colonies begin to produce spores of the septate Fusarium type in 3 to 4 days but if the cultures are allowed to continue their growth for 3 to 4 weeks large number of spores of the obovate type are produced. Figs. 89 to 93 show the different forms of spores which are found in cultures of this fungus, F II and F IV being strains of the same fungus. The obovate spores are as a rule about 8 microns in diameter, the septate vary from 11 to 41 microns in length and from 2.75 to 5.5 in width. They are one to 5-septate and may be straight or curved. According to the system of Appel and Wollenweber the spores which occur in the young cultures on agar are to be regarded as abnormal.

The first thought to occur on finding spores of the obovate and pyriform types in cultures which in other respect are so strikingly similar to typical cultures of Fusarium is that the cultures must not be pure. Plating out and starting from colonies which had developed from single spores gave cultures which produced the different types of spores. Moreover, it is possible to find spores of the long type and of the obovate type cut off from the same conidiophore so that one is forced to the conclusion that the extremely different forms belong to the same fungus.

In the first examinations of fungi of the type of F II found in connection with studies of decaying apples, the writer felt no hesitancy in referring the fungus to that genus on account of its striking similarity to other species of the genus. Later when it was found that the obovate, pyriform, and septate spores belonged to the same fungus the question of its proper classification became more difficult. Of the many species of Fusarium, the writer found none which was described as producing spores of such a strikingly obovate form. However, it is to be remembered that only a comparatively small number of the species of Fusarium were described from material which had been under observation in culture for a long enough time that all of the spore forms could be taken into consideration. For example material of F II collected as it occurs naturally in decaying apples may show in some cases practically all spores of the septate Fusarium type while in other cases the obovate spores predominate. A description of the fungus which took into consideration either of these conditions without regard to the other would not be complete.

Soon after it had been determined that the different spore forms belonged to this fungus, the writer read Stewart and Hodgkiss'* account of the Sporotrichum Bud-Rot of Carnations and the Silver Top of June Grass. Stewart isolated a fungus from decaying carnation buds, studied it in culture and carried on inoculation experiments in which he proved that it caused the rot of the buds. Diseased buds were sent to Dr. Peck who described the fungus as a new species, *Sporotrichum anthophilum*. Some time before this, Stewart had found a similar fungus associated with the silver top of June grass which Dr. Peck had named *Sporotrichum poae*. The descriptions of both species were based on material as it occurs in nature.

When Stewart grew the fungi from the two sources in culture, it was found that they gave exactly the same kind of growth on a number of media. Both were characterized by the production of a large amount of white aerial mycelium and by red color next to the medium. The spores in both were obovate to pyriform with occasional septate spores of the type of Fusarium macroconidia. By means of inoculations, he showed that the fungus isolated from June grass would also cause the rot of carnation buds and therefore concluded that the two species, *S. poae* and *S. anthophilum* should be regarded as one species which should be called *S. poae* because that species name was used earlier than the other.

The writer was impressed by the striking similarity of the carnation bud-rot fungus and the fungus from apples which has been referred to as F II. The fungus from apples agrees with the description of the one from carnations and June grass in its rapid growth, production of a large amount of white aerial mycelium, production of red color on a number of media and in the spores which vary from the obovate type of Sporotrichum to the septate type of Fusarium. The chief difference which is to be noted is that the fungus studied by Stewart is described as producing a predominance of spores of the obovate to pyriform type while in the fungus isolated from apples in Maine the type of spore which predominates varies with the age of the culture and with the conditions of growth.

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* Stewart, F. C., and Hodgkiss, H. E. The Sporotrichum Bud-Rot of Carnations and the Silver Top of June Grass. N. Y. Agr. Exp. Sta. Technical Bulletin No. 7, 1908.

In response to a request for cultures of the carnation bud-rot fungus for comparison with the apple fungus, Stewart replied that after the completion of their studies the cultures had been allowed to die. Some of the old cultures had been saved, however, and these were sent. While the writer did not have the opportunity to see this fungus alive and growing under the same conditions as the fungus from apple, there seemed little reason to doubt that the two fungi were very closly related. The proportion of obovate spores seemed greater in the old cultures which were sent by Stewart than in old growths of the apple fungus. The fact that so few spores of the septate type were found caused Stewart to regard the fungus as being more properly classified in the genus Sporotrichum than in Fusarium, although he points out that no other species of Sporotrichum is described as having septate spores.

At about the same time that Stewart was studying the carnation bud-rot Heald * was investigating a similar disease in Nebraska. In Heald's first account of this disease published in Science † a species of Fusarium was regarded as the cause of the rot but in the later publication the causal fungus is considered to be *Sporotrichum anthophilum*. Later in this paper data will be presented which will show that the fungi encountered in the two cases were not necessarily the same. The writer determined by means of inoculation experiments that certain typical species of Fusarium can cause rot of carnation buds so that it is not impossible that Heald was working with two different fungi.. On the other hand the bud-rot fungus may have shown a large proportion of septate spores in one case and of obovate spores in the other. The illustrations of the fungus in the later publication show no septate spores of the Fusarium type.

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* Heald, F. D. The Bud Rot of Carnations. Neb. Expt. Sta. Bul. 103. 1908.

† Science, N. S., 23:620. 1906.

The writer tried to secure a culture of the fungus but it was no longer available. Dr. Heald kindly offered, however, to examine cultures of the apple fungus and give his opinion as to its identity with the one which he had studied in connection with carnation bud-rot. After growing the apple fungus for some time he reached the conclusion that it was very similar to his carnation bud-rot fungus and should probably be regarded as belonging to the same species.

Soon after noticing the similarity of the carnation bud-rot fungus and the apple rot fungus which had been designated as F II, inoculation experiments were begun in which the one from apple was tested on carnations in order to determine whether it would cause bud-rot. A detailed account of the inoculations and the results is given later in this paper. Here it is sufficient to say that as the result of these inoculations it was found that not only F II would cause the rot of the buds but that what appear to be closely related fungi isolated from other hosts can also produce the same disease. It was also found that certain typical species of Fusarium were capable of causing the destruction of the buds.

Fungi of the same type as the carnation bud-rot organism seem to be quite widely distributed in nature. The question of whether these are to be regarded as strains of one species or as closely related species is a difficult one. A fungus which is very similar to the one associated with the carnation disease was isolated from an ear rot of corn in Illinois and described by Burrill and Barrett.* This fungus which they called Fusarium I from corn produced a large amount of white aerial mycelium which later shows red color next to the culture medium. It was described as producing spores of two kinds, obovate to pyriform microconidia and septate macroconidia of Fusarium.

In the fall of 1910 the writer asked Dr. Barrett if it would be possible to obtain a culture of this fungus for comparison with the apple decay fungus. At that time the cultures had been allowed to die in the Illinois Laboratory but Dr. Barrett offered to look over material of the apple fungus and give his opinion as to its identity with the corn Fusarium I. Later, in the fall of 1911, Dr. Barrett again secured cultures of the corn Fusarium and after growing it and the apple fungus for some time under the same conditions sent a culture (carried in this laboratory as F XXXVI) to the writer with the opinion that the two should be regarded as distinct.

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* Burrill, T. J., and Barrett, J. T. Ear Rots of Corn. Ill. Expt. Sta. Bul. 133, p. 86, 1909.

Examination of material from young cultures of the corn fungus shows that it produces a much greater proportion of obovate spores than does F II from apples. In this it agrees more closely with the carnation bud-rot fungus than do the forms isolated from apples.

In December, 1912, the writer made some study of the fungi associated with the decay of ears of flint corn in Maine. On some ears obovate spores were found and on others septate Fusarium spores. Cultures were made with the result that two strains or species were secured one of which, F XLVIII, produces large numbers of obovate spores with occasional septate spores while the other, F XLIX, produces many septate spores with a much smaller proportion of the obovate form. The first of these fungi agrees closely with the one secured from Illinois while the other seems to be identical with F II from apples, showing that this may also occur on ears of corn. Since in the culture studies the two strains have been found to require the same conditions for growth it is probable that both occur frequently on moldy corn. Not enough work has been done to determine which is the more common in Maine. To determine this would require a large number of isolations of the fungi from different sources and their comparison in culture. On account of the fact that no difference can be noted in their effects on corn the value of this work would be questionable.

In connection with this study, the writer has isolated fungi from a number of sources for comparison with F II from apple. In this way a considerable number of strains have been secured. Some of these have proved to be typical species of Fusarium, while a number although showing certain characteristics of Fusarium have been found to produce spores of the obovate type. In many cases these forms cannot be distinguished from typical species of Fusarium until a microscopic examination is made of the spores.

In May 1910 a diseased potato was sent to this laboratory by Dr. G. E. Stone of the Massachusetts Agricultural College. When material from the diseased surface of the tuber was examined septate Fusarium spores were found. Cultures were made from these and the fungus which developed, F IX, produced an abundance of spores of the obovate type such as had been found in F II from apples. Early in the study of this it was noted that while the growth of mycelium was very similar and the spores identical in shape and size to those of the fungus from apple the proportion of obovate spores was much greater in the potato fungus. With the latter, the septate spores were produced in the young colonies when obovate spores were sown in agar plates but when aerial mycelium began to develop the obovate spores were produced in greater numbers than the septate.

In September 1910 a fungus, F VI, was isolated from diseased ears of sweet corn. The same fungus has been found on sweet corn a number of times since, but it is probable that the total amount of loss caused by it is small. It agrees very closely in its characteristics with F IX described above from potato.

A fungus, F XIII, isolated from diseased heads of sunflower, *Helianthus annuus* L. shows the same characteristics as F II from apple. While in older cultures it produces large numbers of obovate spores there are always present a good proportion of spores of the septate Fusarium type. This fungus causes a complete decay of sunflower heads and destroys the seeds. Upon inoculation the sunflower fungus was found to cause a rot of carnation buds and 47 of the 71 buds inoculated were destroyed.

In June and July, 1911, a number of grasses on the University grounds and farm at Orono showed silver-top. These grasses were examined from time to time in order to determine whether the fungus which Stewart found associated with the silver-top of June grass in New York occurred in Maine and if it did occur to isolate it from as many different grasses as possible for comparison with similar fungi from other sources.

On June 7, 50 culms of June grass, *Poa pratensis,* affected with silver-top were examined and only one was found which showed the spores of a fungus. These spores agreed in size and appearance with those of *Sporotrichum poae.* Dilution plate cultures were made and in three days colonies had developed which were producing spores. These were of both the one-celled, obovate and the septate types. Transfers were made from the colonies in the plates to sterilized bean pods in tubes. When the growth on bean pods was examined three days later it was found that large numbers of the obovate spores had been produced and only a small proportion of the septate type. It will be seen that this fungus, F XXIV, agrees very closely in its characters with *Sporotrichum poae* as described by Stewart. It also agrees closely with Barrett's Fusarium I, F XXXVI, from corn from Illinois and with one of the fungi isolated from potato, F IX, and one from sweet corn by the writer, F VI. The fungus was tested on carnation buds by inoculating 24 buds of the Enchantress variety and 22 of these were destroyed.

After about 2 weeks, June grass was again examined. This time a large number of plants showed the presence of the fungus on the injured culms. The mites which Stewart and Hodgkiss found associated with the fungus were also found here.* The explanation of the common occurrence of the fungus at this time in contrast to its rare occurrence 2 weeks earlier is found in the fact that the second examination was preceded by a period of rainy and cloudy weather which was favorable to the growth of the fungus.

Fowl meadow grass, *Glyceria nervata* (Willd.) Trin. which had been injured by the grass thrips was examined June 28 and showed the presence of a fungus which seemed to be identical with the one from June grass, F XXIV. On July 7 a rather large number of plants were examined and the fungus was found to be of frequent occurrence. Dilution plate cultures were made, F XXVII, and later material was transferred from colonies to tubes of various media where the growth was so nearly the same as that of the June grass fungus that one could not be distinguished from the other.

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* Cary, see pp. 100 and 112 of the 18th Annual Report of the Maine Agricultural Experiment Station, attributes the "silver top" of Jnue grass and certain other grasses in Maine to the grass thrips *Anaphothrips striata* Osborn. Material examined during different seasons showed both the mites and the thrips associated with the diseased plants.

In the same way material was examined from plants of red top, *Agrostis alba* L., F XXV; timothy, *Phleum pratense* L., F XXVIII; and quack grass, *Agropyron repens* (L) Beauv., F XXVI, which had been injured by the grass thrips. In all of these, the fungus was found and isolations were made in each case. A fungus, F XXX, showing the same characteristics was also found associated with silver top of timothy collected in Indiana in July 1911. Another, F XXIX, a typical species of Fusarium was also isolated from some of the diseased culms from Indiana.

An ornamental grass, *Phalaris arundinacea* L. var. *picta* growing on the University campus also showed the presence of the fungus with obovate spores on the shrunken culms which had been injured.

The fungi isolated from these different grasses have the same cultural characters. When they are grown side by side on the same medium, it is impossible to distinguish one from the other. They also agree very closely with the one from potato, F IX, described earlier in this paper, with the fungus from sweet corn, F VI, and with Barrett's Fusarium I from corn, F XXXVI, from Illinois. Some work has been done to determine the relation of these fungi to the carnation bud-rot by means of inoculations of carnation buds. It will be remembered that Stewart produced bud-rot of carnations with the fungus isolated from June grass and from these results reached the conclusion that the fungus from June grass and the one from carnation buds should be regarded as one species, a conclusion which no doubt is correct. In the inoculation work carried on by the writer, there has been wide difference in the results obtained with the very similar fungi from different sources. With the fungi from June grass, F XXIV; red top, F XXV, and quack grass, F XXVI, the proportion of decayed buds was so great as to lead to the conclusion that if the decay of carnation buds is taken as a standard by which to measure their relationship, they would be regarded as one species. Some of the fungi which seem identical with the one from June grass, F XXIV, in cultural and morphological characters did not cause a rot of carnation buds. These include the fungus from fowl meadow grass, F XXVII, Barrett's corn Fusarium I, F XXXVI, and the fungus with obovate spores from potato, F IX. On the other hand a number of cultures of typical Fusarium which could not possibly be considered as belonging to the same species as the fungi with obovate spores have been found to cause rot of carnation buds upon inoculation. It would seem that a number of species can cause carnation bud-rot but that what appears to be one morphological species isolated from different host plants has certain strains which cause the rot and others which do not. The fungus from fowl meadow grass seems identical with that from June grass yet it failed to attack carnation buds of the same variety that were destroyed by the June grass fungus. F II from apple and the sunflower fungus, F XIII, caused rot of the buds which was exactly the same in appearance as that caused by the June grass organism although they differ from it in the production of a much larger proportion of septate spores and might possibly be regarded as belonging more properly to a different species. *Fusarium putrefaciens*, F XII, and F I from apple caused rapid decay of carnation buds and there is no question but that these are typical Fusarium forms.

In the course of this study species of Fusarium have been isolated or secured from a number of different sources and have been carried through periods of growth on the same media as the forms with obovate spores for comparison. Cultures of two species of Sporotrichum, *S. roseolum* Oudem. and Beyer and *S. bombycinum* (Corda) Rabenh. were secured from the Association Internationale des Botanistes and these have been carried in culture for more than two years. These species bear little resemblance to the fungi with obovate spores which are under consideration as they produce almost no aerial growth on any of the media on which they have been grown. The writer has had little experience with the genus Sporotrichum, never having grown but one other species in culture but after growing several fungi of the same general group, if not strains of the same species, as the carnation bud-rot fungus in comparison with a number of typical species of Fusarium, some of which resemble that fungus in certain characteristics, and taking into consideration that Sporotrichum is a genus characterized by producing one-celled spores while Fusarium is a genus in which different types of spores are produced in a given species under different conditions of growth, it would seem that this group of fungi should be considered as more closely related to Fusarium than to Sporotrichum.

Cultures of the fungus which has been called F II from apple showing both obovate, one-celled spores and septate spores were sent to Dr. Peck in March, 1910, together with a letter calling attention to the similarity of the apple fungus to that causing carnation bud-rot and to the fact that in the cultures of the fungus from apple large numbers of spores of the septate type were present. In replying Dr. Peck stated that in describing the fungi from June grass and carnation buds only material as it occurs in nature was examined. For that reason only spores of the obovate type were observed. Dr. Peck also said that he knew of no genus which would properly include a fungus with spores of both the Sporotrichum and Fusarium types. It may be possible that the fungi with these two kinds of spores constitute a group of species which should be placed in a new genus. It is well known, however, that many species of Fusarium produce in culture large quantities of spores of such shape and size as to place them in other genera if the classifications were based on these spores which are usually called micrononidia. The writer believes that the obovate spores in the group under consideration should be regarded in the same way that the small spores of a Cephalosporium type are regarded in certain species of Fusarium and that the fungi with obovate spores agreeing in other characteristics with Fusarium can safely be included in that genus.

As has been stated, a number of typical species of Fusarium have been carried in culture side by side with the fungi already discussed and used to some extent for comparison with them. *F. roseum* Lk, F XVIII, was isolated from scabby wheat which was kindly sent to the writer from Ohio by Dr. Thomas Manns, then of the Ohio Agricultural Experiment Station.* This fungus produces a large amount of white aerial mycelium with bright red color next to the culture medium. In appearance the cultures closely resemble those of F II from apple but microscopic examination shows that the wheat scab fungus produces very few spores in culture and none of these are of the obovate form.

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* See foot-note p. 254.

In September 1910, a Fusarium was found on glumes of wheat in Maine. The fungus, F VIII, was isolated and has been found to agree in cultural characters with F I from apple. There is less aerial mycelium than in *F. roseum,* F XVIII, secured from Ohio and spores are produced in large quantities in sporodochia. These masses of spores are orange colored. When apples were inoculated with this fungus it caused as much decay as F I from apple.

A fungus, F XXXI, isolated from summer squash in the summer of 1911 agrees somewhat closely in cultural characters with F II from apple. There are, however, a very small proportion of spores of the obovate type. The spores agree in appearance with those of other fungi which have been described in this paper. This fungus produces such a large proportion of septate spores that it would seem that its classification should be based on these rather than on the obovate spores. It is difficult, however, to separate the fungi which produce spores of these types and place all which show a large proportion of septate spores in the genus Fusarium and those which produce a smaller proportion in another genus.

A species of Fusarium, F XL, was found causing rot of squashes in storage in December, 1911. This fungus produced much white aerial mycelium with red and yellow color near the medium. The decaying tissues of the squash took on a bright red color.

A fungus, F XVII, similar to the one from squash was isolated from ears of yellow dent corn from Indiana. The growth of this fungus agrees very closely wih that of the one from squash when they are grown on the same culture medium. The corn fungus grew rapidly and produced the same effects on squash as the squash fungus when both were used in making inoculations. Neither of these strains has produced many spores in cultures.

A fungus which agrees in cultural characters with *F. oxysporum* as described by Smith and Swingle * was secured from two sources, Ohio, F XVI, and Vermont, F XV, and these strains have been grown on a number of media.†

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* Smith, Erwin F., and Swingle, Deane B., Bureau of Plant Industry, Bulletin 55, 1903.

† See foot-note p. 254.

A fungus F VII isolated from diseased cucumbers in Maine has agreed closely with these fungi in its growth. This was striking in the experiments testing the effect of different amounts of several acids on growth. In each case these 3 strains were able to grow in media containing larger amounts of acid than any of the other 21 strains used in these tests. Two other species of Fusarium have been obtained from diseased cucumbers. One of these, F XX, shows some blue color in the mycelium while in the other, F XIX the mycelium remains white. All of these strains from cucumber produce large numbers of chlamydospores in the cultures. These chlamydospores may occur singly or several may occur together in the hypha. Two strains from tomato, F XXI and F XXII, and one from squash, F XXIII, agreed closely with the strain from cucumber in which the mycelium remained white.

In addition to the forms from potato which have been mentioned four others have been isolated. One of these, F XXXVIII, which was isolated from sporodochia on stems has shown the same cultural characters as F I from apple, and the fungus, F VIII, isolated from wheat in Maine. When apples were inoculated with the potato fungus, rot followed. The other three fungi illustrate very well the fact that a number of species of Fusarium may occur in stored potatoes and that some of these species can be easily distinguished form one another by their growth on a few culture media. One of these forms, F XXXIII, showed blue color of mycelium, one red, F XXXV, and the other white, F XXXIV, when grown on potato cylinders. These fungi have been under observation for two years and have not shown variation from these colors except in the case of the red which has not been uniform.

Each summer for the past three years specimens of China aster, the stems of which were affected with a fungous disease, have been sent to this laboratory. In each case cultures have been secured by taking material from the inner part of the stem, using sterilized instruments. The cultures secured from different sources give evidence that the same fungus, F XIV, is responsible for the disease in different localities. The fungus shows a small amount of white aerial mycelium and no color has appeared in the cultures. The spores are mostly of the non-septate type but occasional septate spores are seen. Chlamydospores occur in the cultures. No inoculations have been made on China asters.

LIST OF ORGANISMS STUDIED.

F I.	Fusarium I from apple fruit.
F II.	Fusarium II form apple fruit, produces obovate spores.
F III.	Fusarium III from apple fruit.
F IV.	Fusarium IV from apple fruit, produces obovate spores.
F V.	Fusarium from ears of sweet corn from Orono. This did not produce obovate spores.
F VI.	Fusarium from ears of sweet corn from Monmouth. Me. This produces many obovate spores.
F VII.	Fusarium isolated from decaying cucumber. Closely resembles F XV and F XVI from potato.
F VIII.	Fusarium isolated from diseased wheat collected in Maine.
F IX.	Fungus with obovate spores from potato. Isolated by Dr. W. J. Morse from a potato tuber sent from Massachusetts by Dr. Geo. E. Stone.
F X.	Fusarium from Red Astrachan apple. This fungus is identical with F II.
F XI.	Fusarium isolated from a green apple which was decaying on the tree August 1, 1910. This fungus is apparently identical with F I.
F XII.	*F. putrefaciens* Osterwalder.* Culture secured from Dr. Osterwalder in 1910 and carried in culture since that time in comparison with the Maine forms.
F XIII.	Fusarium from sunflower. Isolated from decaying head of sunflower from garden in Orono.
F XIV.	Fusarium from China aster. Isolated from stems of diseased plants sent by Mrs. E. C. Bodman of Seal Harbor, Maine. September, 1910.
F XV.	Agrees closely in cultural characters with *F. oxysporum** as described by Smith and Swingle. This strain was secured from Vermont through the courtesy of N. J. Giddings.
F XVI.	A culture of this fungus which was isolated from internal tissues of potato tuber from Sharpsburg, Ohio, was secured from Dr. Thomas Manns. Fungus seems identical with F XV.

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* See foot-note p. 254.

F XVII.	Fusarium from yellow dent corn. Isolated from decaying ear of corn sent from Indiana. January, 1911.
F XVIII.	*F. roseum* Lk.* Isolated from diseased wheat which was secured from Dr. Thomas Manns then of the Ohio Experiment Station.
F XIX.	Fusarium isolated from decaying cucumber. This fungus differs from F VII in that the mycelium remains white in old cultures while in F VII it takes on some purple color on certain media.
F XX.	Fusarium isolated from cucumber by Dr. W. J. Morse. Grows slowly and produces less aerial mycelium than XIX. Shows some blue color in old cultures. Spores are mostly 3-septate.
F XXI.	Fusarium from tomato. Isolated from decaying tomato. Similar in cultural characters to F XIX.
F XXII.	Fusarium from tomato. This strain seems to be identical with F XXI.
F XXIII.	Fusarium from squash. Isolated from decaying squash. Very similar in cultural characters to F XXI.
F XXIV.	Fungus isolated from June grass which showed silver top June, 1911. This fungus is identical in cultural characters with the one which Stewart isolated from June grass and which he regarded as identical with the carnation bud-rot fungus.
F XXV.	Fungus isolated from red top which showed silver top, 1911. Identical with F XXIV.
F XXVI.	Fungus isolated from quack grass, 1911.
F XXVII.	Fungus isolated from fowl meadow grass, 1911.
F XXVIII.	Fungus isolated from timothy from Maine, July, 1911.
F XXIX.	Fusarium from timothy from Indiana, 1911. This is a typical species of Fusarium and does not show the obovate spores.
F XXX.	Fungus with obovate spores from timothy which showed silver top. From same lot of material as F XXIX. F XXX is identical in cultural characters with the forms isolated from the different grasses in Maine.
F XXXI.	Fusarium isolated from summer squash, July, 1911. This fungus produces a small proportion of obovate spores in cultures.
F XXXII.	Fusarium isolated from diseased stem of garden pea, July, 1911.
F XXXIII.	Fusarium in which the mycelium takes on a blue color. Isolated from potatoes in storage, 1911.

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* See foot-note p. 254.

F XXXIV.	Fusarium with white mycelium from potato. From same lot of potatoes as F XXXIII.
F XXXV.	Fusarium in which the mycelium takes on red color. Isolated from the same lot of potatoes as F XXXIII.
F XXXVI.	Fungus secured from Dr. Barrett from Illinois. This culture was a later isolation which Dr. Barrett regarded as identical with the fungus described as Fusarium I from corn in Illinois Bulletin 133.
F XXXVII.	Fusarium from Milden Apple. Culture from a strain isolated by M. Shapovalov, November, 1912. This fungus is identical in cultural characters with F I.
F XXXVIII.	Fusarium from potato stems. Culture started from sporodochia on stems, September, 1912. There was no evidence that the fungus was growing as a parasite. This strain shows cultural characters identical with F I and it also caused rot of apple fruit upon inoculation.
F XXXIX.	*F. vasinfectum* var *pisi* Van Hall. Culture secured from Centralstelle für Pilzkulturen, September, 1912.
F XL.	Fusarium from decaying winter squash. This fungus which was isolated December, 1911 shows strikingly different cultural characters from F XXIII as F XL produces much white aerial mycelium with red and yellow color near the medium.
F XLIV.	Fusarium from China aster. Isolated from diseased stem of China aster sent from Winter Harbor, Maine, in 1908.
F XLV.	Fusarium from China aster. Isolated from material from Seal Harbor, Maine, August, 1911.
F XLVI.	*F. niveum* Smith. Culture secured from Kral in February, 1910.
F XLVII.	Fusarium strains a, b, c, d, and e. All seem to be the same species as F I unless it is e. Isolated from decaying Milden apples December, 1912.
F XLVIII.	Fungus with obovate spores from flint corn. Same cultural characters as F XXXVI. Isolated from decaying corn from Winslow, Maine, January, 1913.
F XLIX.	Fusarium with small proportion of obovate spores. Isolated from same lot of corn as XLVIII.

CULTURE STUDIES.

On account of the fact that certain species of Fusarium show very different cultural characteristics when grown under different conditions, it is difficult to compare the forms from different sources unless they can be grown on the same medium under the same conditions. The desirability of growing the fungi which are to be compared on a number of culture media should be readily apparent.

In this work comparative studies were begun with the forms isolated from apples and later other fungi were included so that with most of the media forms from 24 sources, F I to F XXIV, were grown on each medium at the same time. This number was used in comparing the effect of different sugars and acids on growth and also in the studies in which fermentation tubes were used.

In all of the work reported here, each form was grown on at least two tubes or plates of the medium and in many cases this was repeated several times. Cylinders of vegetables, as potato, turnip, carrot and beet are very satisfactory media for the growth of species of Fusarium. When potato cylinders are prepared in the same way from time to time and the cultures are kept under the same conditions in other respects there is very little variation in the appearance of the mycelium of a given strain. The writer has observed no striking changes in the cultural characters of certain species of Fusarium which have been grown upon this medium with frequent transfers for four years. The species of Fusarium are usually regarded as very variable, but what have been considered as variations can probably be explained in every case as responses to changed conditions.

Some of the most important characters to be made use of in comparing representatives of this genus are: mycelium as to amount of aerial growth and color, presence or absence of chlamydospores, shape and size of conidia, and with those forms which are parasitic, the extent of the parasitism should be determined by means of inoculations.

Owing to the incompleteness of many of the published descriptions, these characters have little value in placing forms in the described species. The amount of aerial growth and the color of the mycelium may be very different in sets of cultures of the same fungus on different media. A species which on one medium may show much bright red color of the mycelium next to the substratum and extending to the aerial growth may show little or no red color in cultures of the same age on another medium. In this same fungus, other conditions may lead to the production of still other colors. On the other hand there are certain species in which the mycelium remains white whatever culture medium is used. In regard to color, it is not sufficient to state that a form shows a given color without giving some account of the conditions under which this color was produced. In cultures of a given species, the spores may show differences in shape and size. For this reason the measurements of spores as they are usually given in descriptions of species may apply equally as well to the spores of another. Any description of a new species of Fusarium should be based on cultural studies extended enough so that the characteristics which are brought out by growth under different conditions can be taken into consideration.

There are some media, however, which do not have much value in furnishing characters of growth which can be used in the separation of species of this genus. In these studies considerable work was done in comparing the growth of species from different sources on media which contained different amounts of sugars and acids. In general, the conditions which are favorable to the growth of one species seem to be favorable to others. For example, the amount of a given acid which when added to a 2 per cent dextrose broth renders the medium so acid that one of the forms which has been tested will not grow prevents the growth of all. The only exception to this was with the strains F VII, F XV, F XVI, which grew in media which contained enough acid to prevent the growth of other species. The following account gives the cultural characters of a number of forms on different media.

GERMINATION OF SPORES.

The species isolated from apple were studied in hanging drop preparations of the spores and this taken together with observations of the germination of the spores of other species in agar plates gives the basis for the statement that Fusarium spores germinate very readily when they are placed under favorable conditions for growth. Frequently, in cultures where there is a large amount of moisture present, spores germinate soon after they are produced.

Spores of F I from apple, taken from a culture three weeks old on turnip cylinder, were placed in a number of hanging drops of a decoction of apple wood at 4 P. M. The next day at 8 A. M. nearly all of the spores had germinated and in some cases the germ tube had branched. Other cultures were made in the same way at 9 A. M. and when these were examined at 4.30 P. M. all stages of germination were found. In some spores, the germ tubes grow out from the end cells in the direction of the long axis. In other cases, the germ tubes grow from the sides of other cells, the end cells being empty of contents. Fusions frequently take place between the germinating spores as shown in Fig. 94.

Spores of F II from apple taken from a bean pod culture three weeks old were sown in hanging drops of apple wood decoction at 10.30 A. M. At 2.30 P. M. the greater part of these spores had germinated. The next day at 2 P. M. considerable mycelium had developed and many spores were being formed. Most of these were of the long septate type but some obovate spores were seen.

Spores of F III from apple were sown in hanging drops at 9.15 A. M. At 4 P. M. many of these spores had germinated. As a rule the germ tubes grew out from the end cells in the direction of the long axis of the spores but in some cases the germ tubes developed from the sides of other cells.

Spores of F IV from apple, a fungus identical with F II, were taken from an agar plate culture and sown in hanging drops of 2 per cent saccharose broth where they began to germinate in 4 to 5 hours. The large septate spores germinate in the same ways that have been described for spores of the other species from apple. The small non-septate spores germinate after a little longer time than the large septate ones. They may or may not become septate before germination. The mycelium developed rapidly so that at the end of 24 hours a branched growth had formed from a single spore. After two days conidia were being produced. These were mostly of the obovate and pyriform types, although the long type were not rare. Cross walls were not seen in the long spores until after they had separated from the conidiophores.

Spores of F IV from apple, the greater part of which were of the obovate type, were placed in hanging drops of distilled water, potato broth, and dextrose broth at 3.30 P. M. At 8 A. M. the following day many stages of germination could be observed. The obovate spores become somewhat swollen and put out as a rule a single germ tube which soon branches. The spores sown in distilled water germinated well but the growth was soon checked while the mycelium in the broths made good growth and spores were formed.

GROWTH ON VEGETABLE CYLINDERS.

Cylinders of vegetables in tubes make excellent media for the growth of the mycelium of species of Fusarium. At the present time the writer has strains from 50 sources representing, however, a smaller number of species, all of which grow well on cylinders of potato, beet, turnip and carrot. These media and especially the potato are used for keeping the stock cultures and, in addition to this, series of cultures of the different strains have been made in which a number of the fungi are grown on the different vegetables at the same time for comparison.

Potato Cylinders. All of the strains of Fusarium which have been isolated here have been grown on this medium. The amount of aerial mycelium and the color which develops are of value in placing the forms from different sources in large groups. Part of these have produced a large amount of white aerial mycelium with bright red color next to the potato, others have shown a white mycelium with no other color except some browning in old cultures, while others have developed blue color.

The following fungi have shown a bright red color on this medium. F I, F II and F IV from apples together with a number of other isolations from apples which proved to be identical with one or the other of these, all the forms with obovate spores which were isolated from various hosts, *F roseum*,* F XVIII, from wheat sent from Ohio, another Fusarium, F VIII, isolated from wheat grown in Maine, 2 strains, F V and F VI, from ears of sweet corn collected in Maine and another from yellow dent corn from Indiana, F XVII, one from decaying winter squash, F XL, and one from summer squash, F XXXI. This color usually appears in 3 to 7 days after the transfers are made when the cultures are kept at room temperature and exposed to the light from a North window.

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* See foot-note p. 254.

Species of Fusarium from the following sources have been carried in culture on this medium for almost three years and have always shown white mycelium: One species from cucumber, F XIX; two strains from tomato, F XXI and F XXII, probably one species; one from squash, F XXIII; three different isolations from diseased stems of China aster, F XIV, F XLIV, F XLV, and one from decaying potato, F XXXIV A species from stored potato, F XXXIII, and one from cucumber, F XX, have produced blue color.

Beet Cylinders. This medium was favorable to the growth of all the species of Fusarium which were tested upon it. In general the growth on beet is very similar to that on potato with possibly a little more red color in those species which produce it.

F I from apple nearly covered the slants after 4 days growth. One tube showed bright red color at the surface of the liquid and extending up along the glass where the cylinder was in contact with the wall of the tube. There was also some red color over the surface of the slant. The other tube did not show quite so much but there was some mixture of red and yellow. One week later there was little difference in the appearance of the 2 tubes. When the cultures were one month old septate spores were found which measured 4 x 25 to 41 microns.

In the tubes of F II from apple the white aerial mycelium almost filled the space between the slant and the wall of the tube and extended 8 mm. above the top of each slant at the end of four days. Red color showed at this time on the surface of the medium and was especially bright where the cylinder was in contact with the wall of the tube. The amount of aerial mycelium was greater with this fungus than with F I. One week later the red color was becoming dull and some yellow had appeared. There was a small amount of browning in the aerial growth. When the cultures were one month old examination showed the presence of spores of different types. The most abundant were obovate in shape and about 8 microns in diameter but there were many septate spores 4 to 5.5 x 14 to 20 microns and consisting of 2 or 3 cells. There were also non-septate spores of the shape that usually occurs in cultures of Fusarium. No long septate spores were observed at this time.

F III from apple does not make as great a growth on any medium which has been used as the other forms from apples. On the beet cylinder cultures four days old, the mycelium covered a little more than one-half of each slant. There was very little aerial growth and this was white in color. No red color ever appeared in these cultures, although occasionally a little red color has been observed on other media.

The growth of F IV from apple was identical in appearance with what has been described for F II. Spores of the same type were found in the cultures.

Another fungus, F X, which was isolated from Red Astrachan apples which were decaying around the core had exactly the same cultural characters on this medium as F II.

The fungus, F XIII, from sunflower heads produced the same amount of aerial growth, the same colors and the same types of spores as the strains with obovate spores from apples.

Strains of a fungus from potato, F IX, and sweet corn, F VI, which produced both obovate and septate spores with a predominance of the obovate type were grown on this medium and gave cultures which in color and amount of mycelium agreed quite closely with the forms described above from apples and sunflower. Comparisons showed, however, that the cultures from apple and sunflower produced a larger proportion of septate spores than the similar fungi from other sources.

The mycelium of *F. putrefaciens*,* F XII grown over the entire surface of the slants when the cultures were 4 days old. Not so much aerial mycelium had developed as in the forms with obovate spores but about the same amount as in F I from apple. The color differed from that in the Maine form, however, the red and yellow of the European fungus being dull in comparison. The dull red color extended to the aerial mycelium to a much greater extent than in any other fungus in this set of cultures. In cultures one month old large numbers of spores were found. These varied from non-septate spores 8 microns in length to spores 47 microns in length with 5 septa. The spores of this fungus are very similar to those of Fusarium I from apple.

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* See foot-note p. 254.

A strain of Fusarium, F XI, which was isolated from an apple which was decaying on the tree August 1, 1910, and another, F VIII, isolated from wheat collected at Orono in September, 1910, were so similar to Fusarium I from apple when the three fungi were grown on beet cylinders that they could not be distinguished when placed side by side.

F. roseum, F XVIII, from wheat produced a luxuriant growth of white aerial mycelium and bright red color developed next to the medium. There was slightly more aerial mycelium than in the cultures of the fungi with obovate spores. Careful examination of material from these tubes showed only a few spores.

A fungus, F XVII, isolated from decaying ears of yellow dent corn sent from Indiana produced a growth very similar to that of *F. reseum* but there was some yellow color as well as red in the fungus from corn.

The species of Fusarium from cucumber, squash, and tomato grew well on beet cylinders but the amount of aerial mycelium was small in comparison with that of the forms which have been described and the color was white.

The 3 strains from cucumber seem to be distinct species although they agree closely in certain characters. One strain, F VII, has agreed closely with *F. oxysporum,* F XV and F XVI, from potato. On certain media this fungus has produced some purple color. Chlamydospores were formed in the cultures on beet cylinders and the conidia were of the one-celled type for the most part. One of the other strains from cucumber, F XIX, has agreed with this in spore characters but the color has remained white except for some brown in old cultures. The third form, F XX, produces less aerial mycelium than the others, the conidia are mostly three-septate and chlamydospores occur in the cultures. The first two forms would seem to be closely related to each other and to *F. oxysporum* as described by Smith and Swingle while the third should be placed in another group of species.

One Fusarium with white mycelium from squash. F XXIII. and the two strains from tomatoes, F XXI and F XXII, have resembled very closely in their growth the species from cucumber in which the mycelium remained white. These fungi in addition to chlamydospores produced larger rounded cells with a small amount of contents. These cells were as much as 30 microns in diameter in some cases.

Carrot Cylinders. The growth on this medium was so nearly identical with that on beet cylinders that the details will not be given. The most striking characteristic was the early development and brightness of the red color in those strains which have been described as showing this color on potato and beet. There was much red color on this medium at the end of 3 days.

Turnip Cylinders. All of the fungi made a good growth on this medium. There was not so much development of the red color on turnip as on potato. beet and carrot. Microscopic examination showed that the spore production agreed with that on beet.

Synthetic Agar. The species of Fusarium studied produce a good growth of mycelium on this medium which is prepared according to the following formula:

Dextrose	50	g.
Peptone	10	"
Ammonium nitrate	10	"
Potassium nitrate	5	"
Magnesium sulphate	2.5	"
Potassium monophosphate	2.5	"
Calcium chloride	0.1	"
Agar	20	"
Distilled water	1000	c. c.

This agar was titrated and made neutral with NaOH but it was found that upon sterilizing changes took place which rendered the medium somewhat acid. However. the medium which has been treated in this way with NaOH is more satisfactory for the growth of fungi than the same medium without this treatment.

The fungi were grown both in Petri dishes which contained 10 c. c. of the medium and on slants in tubes which contained 5 c. c. The appearance of the growth of a number of the fungi in Petri dishes is shown in Fig. 95 to 104. The development of red color was held somewhat in check on this medium in that it did not appear so early nor spread so rapidly as in the growth on some other media.

F I from apple spread rather rapidly, so that at the end of one week the mycelium had reached almost to the edges of the plates. The amount of aerial growth was less than in F II from apple. Viewed from the under side there was some yellow color and some red, but 3 days later the red color had increased so that one of the plates showed red over more than one-half of the under surface. Large quantities of spores were produced and when these were examined on the tenth day they were found to range from small one-celled to 5-septate spores 55 microns in length.

F II from apple made a very rapid growth on synthetic agar. At the end of one week the Petri dishes, which were almost 10 cm. in diameter, were filled with white aerial mycelium. Viewed from the under side both cultures were slightly yellowish and one showed some reddish color at the center. When the cultures were 10 days old both obovate and septate spores were found in large numbers. More than one-half of these were septate.

All of the strains with obovate spores from various sources have been grown on this medium. They have all agreed in the production of a large amount of white aerial mycelium and in showing some red or yellow color on the under side. The forms from apple and the one from sunflower have differed from the others in the production of a larger proportion of septate spores, but in other characters could not be distinguished from the other strains.

In the young cultures, *F. putrefaciens,* F XII, showed about the same amount of white aerial mycelium as F I from apple. When the cultures were one week old the mycelium took on a yellow color.

The Fusarium which was isolated from an apple which was decaying on the tree, F XI, the one from wheat collected at Orono, F VIII, and F I from apple made a very similar appearance on this medium, adding to the evidence that these strains belong to one species. All produced about the same amount of white aerial mycelium and all showed some yellow and considerable red color when the plate cultures two weeks old were viewed from the under side.

F. roseum. F XVIII, from wheat made a rapid growth and the Peri dishes were completely filled by the white aerial mycelium when the cultures were 5 days old. Later a small area which showed red color appeared at the center of each plate. A small number of septate spores were found in these cultures.

The forms from cucumber, F VII and F XIX, squash, F XXIII, and tomato, F XXI and F XXII, produced a rather large amount of white aerial mycelium. The one species from cucumber, F XX, which has been referred to as making less growth than the others on other media did not spread so rapidly in the plates as the others and could easily be distinguished from them. The culture of this fungus is shown in Fig. 104. All of the forms from cucumber produced chlamydospores.

The Fusarium, F XIV, F XLIV and F XLV, from China aster made a good growth but only a small amount of aerial mycelium developed. The color was white throughout. The spores were nearly all of the small one-celled type.

Prune Agar. The prune agar used in this work was prepared by making a decoction from 6 large prunes for each 1000 c. c. and adding 2 per cent dextrose and 2 per cent agar. It has been found that when too many prunes are used the agar becomes soft and that the use of a small enough number of prunes to give a solid agar makes the medium too poor in food for good growth of fungi. It was thought that adding 2 per cent dextrose to the agar containing the decoction from 6 prunes in 1000 c. c. would overcome both of these difficulties and the results have been fairly satisfactory. Species of Fusarium grow readily on this agar but do not produce aerial mycelium to such an extent as on synthetic agar. Prune agar is a favorable medium for the production of red color in those species which are characterized by the development of that color.

Fusarium forms I, II, and IV from apples spread rapidly over the plates but showed only a small amount of white aerial growth. Red color appeared at the center of the plates in 3 to 5 days and a little later the whole of each plate showed deep red, when viewed from the under side, except for a little yellow in F I. In the plates of F II and F IV the small amount of white aerial growth produced large numbers of spores of the obovate type. When these spores were sown in other plates of prune agar the young colonies first produced long, septate spores and later, on the aerial growth, large numbers of obovate spores developed.

F III from apple developed no aerial mycelium on this medium. When the cultures were 3 weeks old many spores were being formed. These were aggregated in a number of little masses surrounding the center of each plate. The large hyphæ showed some yellow color.

All of the fungi from various sources which have been described as producing obovate spores agreed quite closely with what has been described for the similar strains from apples. Some of these did not produce as large a proportion of septate spores as the strains from apple but all did produce septate spores in young colonies when the obovate spores were sown in plates of prune agar. This has been observed so frequently in forms from different sources as to give evidence that the development of the different types of spore depends to a large extent on the conditions of growth.

F. putrefaciens, F XII, differed very much in its appearance on this medium from the other apple fungi. No red color developed but instead many of the large hyphæ showed a deep yellow color.

The Fusarium from wheat, F VIII, which has been referred to as giving a growth identical with that of Fusarium I and other strains from apple gave further evidence of this relation when grown on this medium as the growth was very similar.

F. roseum, F XVIII, made a rather rapid growth so that 3 days after the transfers were made the colonies were 2.5 cm. in diameter. At that time the central part of each colony was deep red, the color extending out a little more than one-half of the distance from the center to the edge of the growth. At the end of one week, the mycelium covered the entire surface of each plate and showed a deep red color identical with that in the forms with obovate spores. Careful examination failed to show the presence of spores.

The forms from cucumber, tomato and squash produced only a small amount of white aerial mycelium. One of the species from cucumber, F VII, agreed with cultures of *F. oxysporum,* F XV and F XVI, from potato in showing at the center of each plate an area of reddish purple color. All of the species from cucumber produced chlamydospores on this medium.

F. oxysporum, F XV and F XVI, from potato made good growth on prune agar but did not produce much aerial mycelium. When the cultures were one week old, the center of each plate had taken on a reddish purple color for an area of about 4.5 cm. in diameter. At three weeks old, the dark reddish purple color had spread over the entire surfaces of the plates and a small amount of white aerial mycelium had developed. Examination showed large numbers of one-celled spores. Material from near the center of one plate showed chlamydospores.

Prune Decoction. This medium was prepared by cooking 6 large prunes in a part of the water, filtering the decoction and making up the filtrate to 1000 c. c. The fungi were grown in tubes containing 5 c. c. of this material. All of the forms which were tested made some growth but this was not a favorable medium for normal development. The mycelium spread through the liquid and in many cases formed a pellicle on which a small amount of aerial mycelium developed. Material from cultures of different ages was examined and it was found that few spores were produced and that these were abnormal as compared with spores of the same fungus grown on more favorable media.

Sugar Broths. In order to determine whether the growth in media containing different sugars would bring out characteristics which might be used to assist in classification, beef extract broths were prepared each of which contained one per cent of a different sugar and each of the strains, F I to F XXIV, was grown in the different media at the same time for comparison. The sugars used were dextrose, saccharose, lactose, and mannite. It was found that all the strains made good growth of mycelium in each broth but that dextrose and saccharose gave better growth than the others. None of the cultures gave a normal development of spores. The conclusion is that the use of sugar broths has no value in the classification of these fungi.

Growth in Fermentation Tubes.

All of the 24 strains which were used in the other culture work were grown in fermentation tubes. Each fungus was grown in two tubes for each medium and the following media were used: one per cent dextrose, saccharose, lactose and mannite broths, and 5 per cent glycerin broth. None of the fungi grew in the closed end of the fermentation tube in any of these broths and none produced gas so the fermentation tube proved to be of no diagnostic value.

Relation of Growth to Alkali and Acids.

One per cent dextrose broth was used as the basis for the media in testing the effects of different strengths of alkali and acids upon the growth of strains from 24 sources. It was found that all of these fungi made good growth even when large amounts of NaOH were added to neutral dextrose broth. At — 60 of Fuller's scale only a little difference could be noted when the tubes were compared with cultures of the same age growing in the neutral broth. When larger amounts of NaOH were added, the growth was less so that at — 100 a distinct difference could be noted in the amount of growth as compared with the check cultures. There was a small amount of growth in all of the tubes at — 150 NaOH but no growth took place when the medium was made — 200 of Fuller's scale. Not enough difference in the growth of the different forms in relation to the alkalinity of the medium could be observed to be of value in the separation of species.

In determining the amount of acid which prevents the growth of Fusarium, the acids used were hydrochloric, sulphuric, nitric, lactic, oxalic, and formic. Normal solutions of these acids were prepared and these were added to neutral one per cent dextrose broth in sufficient quantity to make the medium of the desired acidity. The same fungi which were used in the other culture work were grown in the media which were the same except for the amount and kind of acid which had been added. Two tubes were used for each fungus with each strength of a given acid. The amount of an acid which prevented the growth of one of the fungi had the same effect on the others except for the strains, F VII, F XV and F XVI, which grew in media which contained sufficient acid to prevent the growth of the others.

Hydrochloric, nitric, and sulphuric acids were unfavorable to the growth of all the forms when added in sufficient quantity to make the broth + 20 of Fuller's scale. At + 40 the growth was very much checked and at + 50 there was no growth. With lactic acid, there was a small amount of growth up to + 100 of Fuller's scale but above + 60 the strains of *F. oxysporum* showed better growth than the others. Oxalic acid checked the growth at + 40 and there was very little growth of any strains except those of the *F. oxysporum* type at + 60. At + 80 no other forms showed growth. With formic acid all of the tubes showed a small amount of growth at + 20, at + 30 there was very little growth and no growth in any at + 40.

GROWTH IN RELATION TO TEMPERATURE.

There was very little growth of any of the 24 forms, F I to F XXIV, when transferred to potato cylinders and kept at a temperature of 5° C., or below. At 15° C. there was good growth but not so much as at 20° to 25° C. When cultures were placed in the incubator at a temperature of 30° C. the growth was not so rapid as at 20° to 25° C. At 33° C. it was less than at 30°, and those forms which produce a bright red color at lower temperatures showed a rather dull red and in a part of the forms yellow instead of red. At 37° C. none of the strains showed growth at the end of one week but when after that time the cultures were removed from the incubator and kept at room temperature most of the fungi made good growth.

GROWTH FROM OLD CULTURES.

Growth from old cultures has been reported for a number of species of Fusarium. By making transfers from time to time it was found that cultures of the species isolated from apples in Maine and also of *F. putrefaciens*, F XII, on bean pods, apple wood, and potato cylinders were alive after a period of 18 months in which the cultures became dried out at the temperature of the laboratory.

TESTS OF PATHOGENICITY.

Apple Inoculations.

Apples have been inoculated with each of the species of Fusarium isolated from apples and also with strains from other sources and it has been found that those isolated from apples and some of the strains from other host plants cause decays of the fruit which are equal in amount and very similar to the rot caused by *F. putrefaciens,* F XII, which has been used for comparison. While these fungi are not so active as causes of decay as the apple rot fungi Sphaeropsis and Penicillium, yet they are capable of causing complete destruction of apples when the conditions are favorable for their entrance and growth.

October 28, 1908, five apples were inoculated with material of F I from a pure culture. The fungus caused a distinct decay and was re-isolated in pure culture from the rotted tissues.

December 5, 1908, five apples were inoculated with material from a pure culture of F II from apple. The fungus soon showed evidence of growth and at the end of five days each apple showed a small decayed area at the point of inoculation. After two weeks the rot had spread to include an area which was from 1.5 to 2.5 cm. in diameter. Pieces of the decaying tissue were removed with a scalpel which was sterilized by flaming and each piece was placed in a Petri dish which contained 10 c. c. of prune agar. The fungus grew out from the tissues in each case and examination proved that the growth was identical with that of the fungus which was used in making the inoculations. The decayed tissue was quite bitter to the taste.

Ten green apples were inoculated August 10, 1909, with material from a pure culture of F I. At the end of 4 days an area about 6 mm. in diameter surrounding each point of inoculation was decayed and some white mycelium had developed. The rot spread slowly but at the end of one month the apples varied from one-half to two-thirds decayed. The diseased tissue was light brown in color, soft, and bitter to the taste when held on the tongue half a minute or more. Plates were made and the fungus was re-isolated in pure culture from the decaying tissues.

Sets of 4 Bellflower apples were inoculated January 4, 1910, with each of the following fungi: F I, II, III and IV from apple, F XV from potato, and F XIV from diseased stem of China aster. After 6 days all of the apples which had been inoculated with the Fusarium forms from apples and with F XV showed decay. The decayed area was about one cm. in diameter in each case and no difference could be noted in the rot caused by these fungi. The fungus from China aster did not cause rot of apples. The appearance of some of the inoculated apples is shown in Figure 111. As much difference could be noted among the apples inoculated with a given fungus as among those inoculated with the 5 fungi from different sources. The taste of the decayed tissue was slightly bitter in all of the apples except those in which the decay was caused by F XV in which no bitter taste could be detected.

August 19, 1910, 6 green apples were inoculated with each of the following fungi; F I, II, and III from apples, F XII, received from Europe, as *F. putrefaciens*, and what was called *F. oxysporum* from each of 2 sources, F XV and XVI. On September 1 all the apples showed some decay but in some cases the amount differed considerably in the 6 apples inoculated with the same fungus. F II caused less decay than the other fungi in this set of inoculations. Figures 108 to 110 show the appearance of the rot on a part of the apples.

Fusarium forms from 16 sources, including strains, F I, F II, F III, F XI, and F XII, from apple, F IX, from potato, F VII, and F XX, from cucumber, F XXII from tomato, F V and F VI from sweet corn, F VIII and F XVIII from wheat, F XIII from sunflower, and F XIV from China aster, were used December 9, 1910, in making inoculations of Greening apples. All made some growth at the points of inoculation but this variety seemed to be resistant to the attack of these fungi and only a small part of the apples showed much decay. There was considerable difference in some cases in the amount of decay in different apples inoculated with the same fungus as has been noted in other sets of inoculations. In this set of inoculations, some of the fungi from other host plants caused as much decay as fungi which had been isolated from apples. It was found that the Fusarium isolated from wheat, F VIII, and which agreed closely with F I from apples caused a distinct decay of these apples. A Fusarium isolated from cucumber, F VII, and which agrees closely with the strains carried as *F. oxysporum* from potato caused as much decay of apples as any fungus which was used in this set of inoculations.

Green McIntosh apples were inoculated August 10, 1911, with strains of Fusarium, F I to F XXVI. The fungi made some growth of mycelium at the points of inoculation but did not spread into the green fruit to cause much decay.

September 1, 1912, Duchess apples were inoculated with strains of Fusarium from 34 sources. Observations from time to time for one month showed that all of these fungi made a little growth but that none of them caused much rot.

January 9, 1913, one Mann apple and 2 Baldwins were inoculated with material of each of 7 strains of a fungus, F XLVII, of the type of F I from apple. Each strain was isolated from a different decaying Milden apple.

One week after inoculation there was a decayed region about 1.5 cm. in diameter at each of the two points of inoculation on each Mann apple. Little difference could be noted in the decay caused by the different strains. The decay spread more slowly in the Baldwin than in the Mann apples. One month after inoculation the Mann apples were almost entirely rotted while the Baldwins showed decayed areas 2 to 3 cm. in diameter.

January 17, 1913, Bellflower apples were inoculated with 40 strains of Fusarium isolated from different sources. One week later all of the fungi showed some growth at the points of inoculation. The strains of F XLVII from Milden apples caused decay more rapidly than any of the others. Later observations showed that strains of this fungus whether isolated from apples, wheat, or potato caused more decay of apples than any other forms used. The forms with obovate spores from various sources did not cause nearly so much decay in this set of inoculations as the fungi of the type of F I from apple. There was in some cases considerable difference in the amount of decay in different apples inoculated with material from the same culture. The results of the inoculation work would seem to justify the conclusion that a number of species of Fusarium may cause decay of apple fruit but that strains of one species are more actively parasitic than the others.

INOCULATIONS OF PEARS.

Three pears were inoculated September 16, 1909, with material of F II from apple. The fungus spread rather rapidly through the tissues and caused the complete decay of the pears. The mycelium of the fungus grew out over the surface forming little tufts.

August 16, 1910, 3 green pears in each case were inoculated with F I, II and III from apple and with F XII, the organism carried as *F. putrefaciens*. Eight days later each of the pears showed a decayed area about one cm. in diameter. F XII and F I grew out around the points of inoculation producing mycelium of a dull red color. F II and III showed white aerial mycelium at the points of inoculation and Fusarium II was producing large numbers of spores, most of which were of the obovate type although some septate spores were observed. One month after the time of inoculation the entire surface of each pear inoculated with F XII or with F I was covered by mycelium which showed red, yellow and white colors. These two fungi gave a very similar appearance on the decaying pears. Fig. 112 to 114 are illustrations showing the extent of the decay 17 days after the time of inoculation.

POTATO INOCULATIONS.

Potato tubers have been inoculated a number of times with each of the Fusarium forms isolated from apples as well as with forms from other sources. The potatoes were inoculated by making a small injury with a sterilized needle or scalpel and placing in this a small amount of fungus material from a pure culture. The inoculated tubers were kept in closed glass jars at the temperature of the laboratory. Nearly all of the fungi made some growth at the points of inoculation but this did not spread into the uninjured tissues to cause decay. Surface injuries to the potato tuber soon become dried out and covered by a corky layer which prevents the entrance of the mycelium unless the tubers are kept under conditions of considerable moisture.

Cucumber Inoculations.

Species of Fusarium have been isolated from decaying cucumbers a number of times at this laboratory. In order to determine the extent to which these species and others would cause decay, cucumbers were inoculated with material of the forms isolated from cucumber, F VII, F XIX, F XX, squash, F XXIII, China aster, F XIV, sweet corn, F VI, apple F XII, and F II. All of these fungi caused a rapid decay. The appearance of 2 of the inoculated cucumbers is shown in Figs. 117 and 118.

Inoculation of Carnation Buds.

Owing to the similarity in cultural characteristics of the fungus with obovate spores from apple and the carnation bud rot fungus described by Stewart and Heald, it was decided to test the apple fungi on carnation buds in order to determine whether or not they would cause the bud rot. Later, the work was extended to include fungi from a number of other sources, a part of which were typical species of Fusarium. Four varieties of carnation were used,—Enchantress, Windsor, Gomez and Lady Bountiful. All of these, except the Gomez, were susceptible to the attack of part of the fungi which were used in making the inoculations. This variety proved to be very resistant and only a very small per cent of the Gomez buds were injured by any fungus which was tested. The Enchantress was used to a greater extent than either of the other varieties in comparing the amount of injury caused by different fungi.

All of the inoculations were made in the same way. A small injury was made in the side of the bud with a sterilized needle and a small amount of material from a pure culture was pushed in through the opening. Usually this material consisted of both mycelium and spores. In a few of the earlier experiments, the plants bearing inoculated buds were placed under bell-jars so that the buds were in a moist atmosphere favorable to the growth of the fungus. This procedure was followed for only a very short time as it was felt to be desirable to test the fungi under greenhouse conditions rather than under the abnormal conditions of a moist chamber.

The detailed account of a number of inoculation experiments follows. In the first part of the work only a small number of plants were available so the number of buds used in the earlier experiments was necessarily small.

Two buds of the Enchantress variety were inoculated March 4, 1910, with material of the apple fungus, F IV. The plants were placed under bell-jars and were kept covered for three days. At the end of this time it could be noted that the fungus was making some growth at the points of inoculation. The buds did not increase much in size and 12 days after inoculation the calyx of each bud appeared somewhat discolored. One bud was examined and it was found that all parts inside the calyx were destroyed by the fungus. When material from the decayed petals was teased out on a slide and examined with a microscope, spores of both the obovate and septate types were found, although the number of either kind was not great. The outer covering of the other bud was removed with instruments sterilized by flaming and the inner decaying part was placed in a tube containing 5 c. c. of sterile distilled water. White aerial mycelium grew out from this and the second day large numbers of spores were being produced, a part of which were obovate and a part of the long septate type. After 5 days the mycelium formed a thick red pellicle over the surface of the water. The white aerial mycelium was bearing many spores of the obovate and pyriform types which agreed in size with the spores of the carnation bud rot fungus.

April 21, 1910, 3 Enchantress buds were inoculated with F IV from apples. One of these buds was removed and examined 4 days later when the fungus showed only a small amount of growth. Two days later one of the other buds was examined and it showed that the fungus was making considerable growth in the tissues. April 29, 8 days after inoculation, the third bud was examined. All parts inside the calyx were destroyed and spores of the fungus were found. It is probable that if the first 2 buds had not been examined until 8 or 10 days after inoculation they would have shown a greater amount of decay as the fungus was growing in each at the time of examination and it has been found that about 10 days are necessary under favorable conditions for the complete destruction of the buds.

On account of the similarity in cultural characteristics of the fungi with obovate spores and certain species of Fusarium it was decided to test a number of fungi which gave evidence of being typical species of Fusarium to see if these also would cause decay of carnation buds.

April 20, 1910, 3 buds of Enchantress were inoculated with F I from apple and check punctures to which no fungus material was added were made in 2 buds. Five days later one of the buds, which was large at the time of inoculation, had opened and showed no decay. April 27 both of the others showed all inside the calyx destroyed and large numbers of spores of the fungus used in making the inoculations were present. One of the check buds was entirely open April 30 and showed no decay, the other opened a few days later and showed no injury from the puncture.

Since F I had caused decay another typical culture of Fusarium later found to be identical with F I was tested. April 28, 4 small buds were inoculated with F III from apple. One week later one of these was examined and it showed a small amount of decay of the petals and stamens. May 9 two other buds were examined and they showed more decay than was noted in the one examined May 5. When the last bud was examined, May 11, the interior was badly decayed.

May 5, 1910, 4 buds were inoculated with F III. May 16, 3 of the buds were badly rotted while the fourth remained healthy.

Five Enchantress buds were inoculated with F IV May 5 and were all badly rotted one week later. Three buds inoculated with the same fungus May 18 were decayed at the end of one week.

May 12, 1910, 2 Enchantress buds were inoculated with each of the fungi, F I, II and IV, from apple. All of these 6 buds were destroyed by the fungi within 10 days.

F XII, the organism carried as *F. putrefaciens*, is in every respect a typical species of the genus. July 11, 1910, 26 Enchantress buds were inoculated with this fungus. Eight days later, 21 of the buds were badly rotted. Material from a part of these was examined and septate spores of the Fusarium were found with no evidence of the presence of any other fungus.

July 26, 1910, 12 buds were inoculated with F XII and punctures were made in 13 buds to serve as checks. The injuries to the check buds were exactly like those in the others except that no fungus material was placed in the wounds. Examination 11 days later showed that all of the 12 inoculated buds were ruined by the fungus while the 13 checks were opening and showed no bad effects from the punctures.

F II from apple was used in making inoculation of 42 Enchantress buds July 11, 1910. Eight days later, 34 of these were badly decayed, 4 showed a small amount of injury and 4 were not damaged at all by the fungus. Eight buds were inoculated with F II July 26, 1910, and 11 days later all were rotted while one bud which had been punctured as a check had opened to a perfect flower except for the place broken by the puncture.

F XV from potato was used in making inoculations of 30 Enchantress buds August 18, 1910. None of these buds decayed. September 14, 13 buds were inoculated with the same fungus and 6 of these showed a small amount of rot, although the fungus did not spread through the tissues so rapidly as the different strains from apples.

August 26, 1910, 25 buds were inoculated with F IV and all of these rotted.

September 15, 1910, 18 buds were inoculated with F I and 30 buds with F III from apple. Of the 18 buds inoculated with F I, 11 decayed and of the 30 inoculated with F III, 20 decayed

The fungus, F XIII, with both obovate and septate spores from sunflower was used October 17, 1910, in making inoculations of 18 buds of Enchantress. Two weeks later 10 of the 18 buds had been destroyed by the fungus.

The Gomez variety was found to be very resistant to the fungi which caused a rot of Enchantress and other varieties which were used in later experiments.

Fourteen Gomez buds were inoculated August 26, 1910, with F I from apple. When these were examined 18 days later only one had rotted.

September 30, 1910, 37 Gomez buds were inoculated with the fungus, F XIII, from sunflower. Only 4 of these buds showed rot after 17 days.

F II from apple was used in making inoculations of 95 Gomez buds November 3, 1910. Observations from time to time indicated that the fungus was not causing decay and that the buds were developing normally. When a careful examination was made November 21 it was found that nearly all the buds had opened into perfect flowers. A few were slightly injured but none badly rotted.

In 1911 tests were made of part of the fungi which had been used in 1910 on 2 other varieties of carnation, Lady Bountiful and Windsor, and a number of fungi which had not been used in 1910 were tested on these varieties as well as on Enchantress.

May 4, 1911, 37 Enchantress buds were inoculated with F II from apple and punctures were made in 22 buds as checks. May 22, 20 of the inoculated buds showed decay and one of the 22 checks had become infected and was also rotted.

May 24, 1911, 30 Enchantress buds were inoculated with F II from apple and 37 with the organism carried as *F roseum,* F XVIII from wheat. Three buds of Lady Bountiful and 5 of Windsor were inoculated with F II from apple. June 6, 10 days after inoculation, 24 of the 30 buds inoculated with F II showed rot, all of the Lady Bountiful had rotted, 3 of the 5 Windsor had decayed. Of the 37 buds inoculated with F XVIII, 25 were destroyed by the fungus.

June 12, 1911, 24 buds were inoculated with material of the fungus, F XXIV, from June grass from a bean pod culture 3 days old, 22 buds with material from a potato cylinder culture 5 days old of the fungus, with obovate spores, F IX, from potato, 15 buds with material from a potato cylinder culture 5 days old of the fungus, F XIII, from sunflower, and check punctures were made in 10 other buds, June 21, 9 days later, 22 of the 24 buds inoculated with the fungus from June grass were decayed and all of the 15 buds inoculated with the fungus from sunflower were destroyed by the fungus. None of the 22 buds inoculated with the fungus from potato and none of the 10 checks showed any rot.

The fungus, F XXVI, isolated from quack-grass was used July 7, 1911, in making inoculations of 7 Enchantress, 6 Lady Bountiful and 12 Windsor buds. July 21, 6 of the 7 Enchantress, 5 of the 6 Lady Bountiful and 10 of the 12 Windsor were rotted. Examination of material from some of these showed the presence of many spores of both the septate and obovate types.

Eleven Enchantress, 7 Lady Bountiful and 12 Windsor buds were inoculated July 25 with material of the fungus, F XXV, from red top. Two weeks later, 8 of the 11 Enchantress, 5 of the 7 Lady Bountiful and 9 of the 12 Windsor were decayed.

The fungus from fowl meadow grass, F XXVII, which is identical in appearance in culture with the fungi from the other grasses was used September 27, 1911, in making inoculations of 16 Enchantress, 6 Lady Bountiful, and 6 Windsor buds. None of these buds decayed.

The fungus, F XXX, isloated from culms of timothy collected in Maine was used August 11, 1911, in making inoculations of 3 Lady Bountiful, 2 Enchantress and 15 Windsor buds. Ten days later 2 Lady Bountiful, 1 Enchantress and 7 Windsor buds were decayed. Great numbers of spores of the obovate form were found but there was no evidence of the presence of any other fungus.

November 21, 1911, 27 Enchantress, 15 Windsor, and 7 Lady Bountiful buds were inoculated with F IV from apple. Two weeks later, 22 of the Enchantress, 7 of the Windsor and 5 of the Lady Bountiful buds were rotted. This fungus had been carried in culture for about 2 years but still remained actively parasitic.

The fungus from corn, F XXXVI, which was designated Fusarium I by Burrill and Barrett was received from Dr. Barrett in November, 1911. December 13, 7 Enchantress, 6 Lady Bountiful and 8 Windsor buds were inoculated using material of this fungus from a potato cylinder culture 12 days old. None of these buds decayed.

The results of the rather large number of inoculations with fungi from different sources would indicate that a bud rot of carnations very similar to that described as due to *S. poae* may be caused by a number of different fungi some of which at least are typical species of Fusarium. A number of fungi which produce obovate and septate spores and agree in cultural characters with the carnation bud rot fungus were tested and most of these caused the rot. Three strains which appear to be very closely related to the carnation bud rot fungus in morphological and cultural characters failed to cause the rot. These were the fungus isolated from potato tuber, F IX, the one from fowl meadow grass, F XXVII, which is identical in appearance with the strains from the other grasses and the fungus from corn sent from Illinois by Dr. Barrett. Whether the failure of these fungi to cause the rot was due to the conditions at the time of inoculations or to the fact that these strains were not pathogenic to the carnation bud might be open to question. However, this point seems to have been determined rather definitely by inoculating a number of buds of the same variety with very similar fungi from different sources at the same time. The experiment of June 12, 1911, will illustrate this. The fungi used were the strain from June grass, F XXIV, which seems to be identical with *S. poae* as described by Stewart, the fungus with obovate spores from potato tuber, F IX, and the fungus from sunflower, F XIII. The material for all of the inoculations was taken from young actively growing cultures. Nine days after inoculation 22 of the 24 buds inoculated with the fungus from June grass and all of the 15 buds inoculated with the sunflower fungus were decayed. None of the 22 buds inoculated with the potato fungus showed any rot. Since the carnations were all of the same variety, Enchantress, and the different lots were growing side by side in the greenhouse, the fungus from potato had the same conditions for the attack of the buds as the other 2 fungi and the only conclusion which the writer can reach from the results is that the patoto fungus is not parasitic on carnation buds. This fungus resembles the carnation bud rot fungus more closely than do a number of other fungi which caused a rot of the buds. The fact that 2 other strains which are so like the fungus from June grass that it is impossible to distinguish cultures of one from the others failed to cause the rot of the buds would seem to indicate that certain strains are unable to go from one host to another. The most striking example of this was the fungus from fowl meadow grass, F XXVII. This fungus seemed identical in cultural characters with the strains from other grasses and yet it failed to cause the rot of carnation buds while the other strains caused the rot in a rather large proportion of the inoculations.

In his first account of carnation bud rot, Heald regarded a species of Fusarium as the cause of the disease. In his later publication, the fungus described was identical with the one described by Stewart as *Sporotrichum poae* and it was regarded as *S. anthophilum* which Stewart proved to be the same as *S. poae*. The inoculation experiments reported in this paper prove conclusively that a number of typical species of Fusarium cause a rot of carnation buds upon inoculation. Therefore, it is possible that Heald worked with different fungi, one a typical

Fusarium and the other the fungus with both obovate and septate spores, or it may be possible, as Stewart believed, that Heald's fungus showed at one time a predominance of septate spores and at another time of obovate spores and in that way led Heald to classify it at one time as Fusarium and later as a Sporotrichum.

The writer has found 3 types of fungi capable of causing the rot: first those with a predominance of obovate spores, as in the fungus from June grass, F XXIV; second, those which produce large numbers of both obovate and septate spores as in F II from apple and the fungus from sunflower, F XIII; and, third, certain typical species of Fusarium which produce no obovate spores as F I from apple and the fungus carried as *F. roseum,* F XVIII, from wheat. From the results of his inoculation experiments and culture studies Stewart concluded that his carnation bud-rot fungus, the fungus from June grass, and Heald's carnation fungus were identical. This conclusion is probably correct, yet attention should be called to the fact that emphasis should be placed on the cultural and morphological characters as well as on the results of inoculations because it has been shown that a number of species which are quite distinct in morphological characters may cause the rot of the buds.

The fact that a number of species or strains from different sources may cause the rot makes the question of control a more difficult one than it would be if only one fungus were responsible for the trouble. Heald regarded the bud rot as serious only in neglected houses while Stewart reported cases in which considerable loss occurred in houses which were well cared for. The fact that the fungi which cause the rot attack no other part of the plant than the interior of the bud would seem to indicate that in order to reach this part the fungus would have to enter through a wound in the calyx. In the greenhouse where the inoculation experiments reported in this paper were carried on, decay of buds which had not been inoculated was of very rare occurrence. In a very few instances, check buds in which punctures had been made were attacked by the fungi. The writer believes that as a rule in houses where every precaution is taken to remove and destroy material which might carry infection and where good conditions for growth are maintained there will be little trouble from the attacks of these fungi.

When it is considered that a vast number of spores may be produced on one diseased bud the necessity for great care in this work becomes apparent.

SUMMARY.

Species of Fusarium occur on a large number of host plants. A part of these fungi are destructive parasites. Owing to the confused condition or the classification of the species of this genus it is frequently difficult to distinguish a parasitic species from a saprophyte which has some similar characteristics. In many cases the same fungus has been described under a number of different names. In order to compare the fungi from different sources, it is necessary to grow them in culture under the same conditions. However, there is a wide difference in the value of different media for this purpose. Liquid media and agars give an abnormal growth as compared with the growth of the fungus on more favorable media such as cylinders of vegetables and other plant parts. Wollenweber * considers stems of plants the best medium for normal development of species of Fusarium.

In order to determine the extent of the parasitism of a given species it is necessary to carry out inoculation experiments. In some cases the same morphological species occurs on more than one host plant and it is only by inoculations that the question can be answered as to whether the strains occurring on one host can cause disease in another.

Two species of Fusarium have been isolated from Maine apples and it has been found that each of these is capable of causing decay. One of these, F I, agree quite closely with the organism received as *F. putrefaciens,* and which was described by Osterwalder as a cause of apple decay in Europe. The same fungus was isolated from diseased glumes of wheat, F VIII, and from potato stem, F XXXVIII. These strains also caused rot of apple fruit upon inoculation. One of the species, F II and F IV, from apple produces obovate spores similar to conidia of Sporotrichum in addition to typical septate Fusarium spores. This fungus resembles very closely in cultural characters the fungus which was described as the cause of a rot of carnation buds under the name *Sporotrichum poae* by Stewart. The chief difference is in the larger proportion of septate spores in the apple fungus. Similar strains have been isolated from a number of other hosts. All of these except one strain from sunflower, F XIII, and one from ears of flint corn, F XLIX, agree closely with the carnation bud-rot fungus in the proportion of septate and obovate spores. The strain from apple and the one from sunflower cause a rot of carnation buds which is identical with that caused by a strain from June grass which appears to be identical with the fungus described by Stewart. The writer believes that all of the strains which have both obovate and septate spores mentioned in this paper are closely related and that they constitute a group of species, each of which has strains occurring on a number of hosts. These fungi seem to be closely related to Fusarium in cultural characters and in being parasitic on plants. The chief difference between the form from apple and the one from June grass is in the proportion of septate spores. A fungus from summer squash, F XXXI, produces a few obovate spores in culture but the proportion is much less than in the form from apples. Thus there can be built up a series extending from strains in which most of the spores are of the septate Fusarium type with a few obovate spores to those with a small proportion of septate spores. Such a fungus as the one from summer squash would seem to be properly classified in the genus Fusarium but the other forms with the two types of spore are so similar to this one in cultural characters that all seem so closely related as to comprise a group. It may be possible that this group of species should be placed in another genus but after growing certain strains in comparison with species of Fusarium for a long period of time on a number of culture media the writer believes that the fungi with both septate Fusarium spores and obovate spores show closer relationship to Fusarium than to any other genus.

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* Wollenweber, H. W. Studies on the Fusarium Problem. Phytopathology 3 : 25, 1913.

Inoculation experiments proved that strains of the fungi with obovate spores from a number of hosts as well as certain typical species of Fusarium cause a rot of carnation buds which seem identical with the disease described by Stewart and by Heald as due to Sporotrichum. Since the inoculation experiments show that not all the species or strains are confined to a single host plant in their parasitism, a large amount of work in cross inoculation experiments will be necessary in determining the extent to which each species may cause disease.

CONCLUSION.

Plant pathologists have felt the need of a comprehensive piece of work in which species of Fusarium from a large number of sources would be grown in culture under uniform conditions so that their classification could be based on the characteristics brought out in the cultures. In 1910 the first part of a monograph of this genus, based on this method, was published by Appel and Wollenweber.* By their methods of culture, what they consider normal development is secured and cultures from different sources can be compared.

Later, in the winter of 1911, Dr. Wollenweber came to this country to study American forms. Realizing the importance of this work, the writer turned over to him transfers from cultures of 35 strains from various sources in February, 1912. These are being studied in culture according to Dr. Wollenweber's methods and it is expected that matters of interest in regard to their classification will be included in a part of the monograph to be published later.

It was hoped both by Dr. Wollenweber and the writer that part or all of the strains would be classified in time so that the names could be included in this paper, but on account of other work only a limited amount of time could be given to these cultures and for that reason Dr. Wollenweber made only a preliminary report on the classification of a part of the fungi.

APPENDIX.

Shortly after Dr. Lewis severed his connection with this Station Dr. Wollenweber made a more detailed report of his conclusions with regard to the relationship of the cultures of the various strains of Fusarium which had been received by him from Maine. Since Dr. Lewis' paper had been written up largely from the standpoint of the data obtained from his own studies and independent conclusions it would, in a measure, destroy its individual value as well as tend to obscure the important features of Dr. Wollenweber's report were the latter to be incorporated within the body of the former. Moreover to do this would necessitate making an entire recast of the article which for several reasons is impracticable and would lead to still farther delay in publication. Therefore, it seemed best to include this report in the form of the following tables, along with certain explanatory matter and comments, as an appendix to the original paper.

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* See foot-note p. 209.

Attention is called to the fact that Dr. Wollenweber has determined the species without knowing the results of Dr. Lewis' studies on their pathogenicity. Only a list of the hosts from which the species were isolated was furnished when the original pure cultures were delivered to him for determination. As will be seen in the discussion following the table most of the species are already described or have been mentioned in the literature upon the subject. In case complete descriptions are lacking he will include them in his monograph or some other publication in the near future. He has very kindly consented to this preliminary publication of the names previous to the final and more complete description. However characters considered to be important for the differentiation of new forms and new combinations have been furnished by him and are briefly discussed in the following pages.

LIST OF SPECIES OF FUSARIUM AS DETERMINED BY DR. WOLLENWEBER.[†]

F I	1171	*F. pirinum* (Fries) Sacc.............	Apple fruit
F II	1172	*F. helianthi* Sacc. (s. var.)..........	“ “
F III	1173	*F. pirinum*	“ “
F IV	1254	*F. helianthi*	“ “
*F V			Sweet corn
F VI	1269	*F. poae* (Peck) n. n.................	“ “

[†] In the above list the Roman numerals preceded by the letter F designate the names under which the different strains or cultures of Fusarium are carried in this laboratory. The second and third columns give Dr. Wollenweber's serial, laboratory number and his determination of all the cultures sent him, with two exceptions, F X and F XI. The last column gives the source from which each culture was obtained. Those marked (*) were not sent to him. Attention is called to the fact that F XII, F XV (including F XVI), and F XVIII, received by and carried in this laboratory as *F. putrefaciens* Osterwalder, *F. oxysporum* Smith and Swingle, and *F. roseum* Lk. and referred to by these names throughout his paper by Dr. Lewis are designated as *F. pirinum* (Fries) Sacc., *F. orthoceras* App. and Wr., and *F. reticulatum* Mont. by Dr. Wollenweber.

F VII	1260	*F. orthoceras* App. & Wr.	Cucumber
F VIII	1272	*F. metachroum* App. & Wr.	Wheat
F IX	1247	*F. poae*	Potato tuber
F X	1252	(Not determined)	Apple fruit
F XI	1253	(Not determined	“ “
F XII	1255	*F. pirinum*	“ “
F XIII	1250	*F. helianthi*	Sunflower
F XIV	1251	*F. conglutinans* Wr.	China aster
F XV	1242	*F. orthoceras*	Potato tuber
F XVI	1243	*F. orthoceras*	“ “
F XVII	1270	*F. discolor* var. *majus* n. var.	Dent corn
F XVIII	1273	*F. reticulatum* Mont	Wheat
F XIX	1259	*F. reticulatum*	Cucumber
F XX	1261	*F. argillaceum* (Fries) Sacc.	“
F XXI	1248	*F. citrinum* n. sp.	Tomato
* F XXII			“
F XXIII	1256	*F. reticulatum*	Squash
F XXIV	1268	*F. poae*	June grass
F XXV	1265	*F. poae*	Red top
F XXVI	1266	*F. poae*	Quack grass
F XXVII	1267	*F. poae*	Fowl meadow grass
F XXVIII	1262	*F. poae*	Timothy
F XXIX	1264	*F. reticulatum*	“
F XXX	1263	*F. poae*	“
F XXXI	1258	*F. helianthi*	Summer squash
F XXXII	1249	*F. orthoceras*	Garden pea stems
F XXXIII	1244	*F. solani* (Mart.) App. & Wr.	Potato tuber
F XXXIV	1245	*F. conglutinans*	“ “
F XXXV	1246	*F. helianthi*	“ “
F XXXVI	1271	*F. poae*	Dent corn
* F XXXVII			Apple fruit
* F XXXVIII			Potato stems
* F XXXIX		(Received as *F. vasinfectum* var. *pisi* van Hall)	
F XL	1257	*F. culmorum* (W. Sm.) Sacc.	Squash
* F XLIV			China aster
* F XLV			“ “
* F XLVI		(Received as *F. niveum* Smith)	
* F XLVII			Apple fruit.
* F XLVIII			Flint corn
* F XLIX			“ “

According to their relationships Dr. Wollenweber has arranged these species in sections of the genus as follows:

Section Martiella: *F. solani, F. argillaceum.*

Section Elegans: *F. orthoceras, F. conglutinans, F. citrinum.*

Section Discolor: *F. discolor* var. *majus, F. culmorum, F. reticulatum.*

Section Roseum: *F. pirinum, F. metachroum, F. helianthi.*

Section Sporotrichella: *F. poae.*

Dr. Wollenweber makes the following comments with regard to certain species.

"*F. culmorum* W. G. Smith is identical with *F. rubiginosum* App. and Wr.

F. citrinum is a new species, differing from *F. orthoceras* App. and Wr. mainly in the absence of a blue color but the presence of a citric color of the mycelium thallus grown on sterilized potato tuber.

F. discolor var. *majus* is a variety of *F. discolor* App. and Wr. having larger conidia and a higher average septation. This variety needs further study as well as *F. argillaceum*, *F. reticulatum*, *F. pirinum* and *F. helianthi*. The latter species described as *F. roseum* var. *helianthi* by Saccardo is interesting by the presence of a pyriform microconidial stage, which shows some relation to the corresponding stage of *F. poae*.

The rest of the species have been partly described in Appel and Wollenweber, Grundlagen einer Monographie der gattung Fusarium, 1910, and partly by the latter author in 'Studies on the Fusarium Problem.' Phytopathology, 1913. In this latter paper the sections mentioned above are given with the exception of Sporotrichella, which might be provisionally established for species with small globose to pyriform but also sickle-shaped, septate conidia of the type of *F. poae* (= *Sporotrichum poae*)."

In studying the combined results of these investigations two interesting facts are presented. First it is apparent that in some instances quite a number of different forms or species of Fusarium have been found associated with the diseased tissues of the same host plant, and second that some are quite omnivorous in their habits and occur upon several hosts. Since the great majority of the species of this genus are saprophytes or are at most wound parasites these observations are by no means new or novel. However, these facts may be of considerable importance from an economic standpoint and they are much more apparent when the strains of Fusarium studied are arranged in the form of a host index and in the form of a list which gives the number of different hosts from which the same strain was isolated or in which it was found capable of causing disease upon inoculation.

HOST INDEX.

Apple fruit, (*Pyrus malus* L.)
F. pirinum, F. helianthi (sub var.)
China aster, (*Callistephus hortensis* Cass.)
F. conglutinans.
Dent corn, (*Zea mays* L.)
F. discolor var. *majus, F. poae.*
Flint corn, (*Zea mays* L.)
F. poae, (F XLVIII and XLIX. not studied by Dr. Wollenweber).
Sweet corn, (*Zae mays* L.)
F. poae.
Cucumber, (*Cucumis sativus* L.)
F. orthoceras, F. reticulatum, F. argillaceum.
Fowl meadow grass, (*Poa triflora* Gilib.)
F. poae.
June grass, (*Poa pratensis* L.)
F. poae.
Quack grass, (*Agropyron repens* (L.) Beauv.)
F. poae.
Red top, (*Agrostis alba* L.)
F. poae.
Timothy, (*Phleum pratense* L.)
F. poae, F. reticulatum.
Pea, (*Pisum sativum* L.
F. orthoceras.
Potato (*Solanum tuberosum* L.)
F. poae, F. orthoceras, F. solani, F. conglutinans, F. helianthi, F XXXVIII. (The latter not studied by Wollenweber but according to Lewis is identical with *F. pirinum.*)
Summer squash (*Cucurbita pepo* L.)
F. helianthi
Winter squash (*Cucurbita maxima Duchesne*)
F. reticulatum, F. culmorum.
Sunflower (*Helianthus annuus* L.)
F. helianthi
Tomato (*Lycopersicon esculentum* Mill.)
F. citrinum.
Wheat (*Triticum sativum Lam.*)
F. metachroum, F. reticulatum.

LIST OF SPECIES GIVING HOSTS FROM WHICH THEY WERE ISOLATED AND SUMMARY OF INOCULATION TESTS.

F. argillaceum (Fries) Sacc., from cucumber.
Produced decay of cucumber on inoculation.
F. citrinum nova species, from tomato.
F. conglutinans Wr. from china aster and potato.
Caused decay of cucumber but not of apple fruit (?).

F. culmorum (W. Sm.) Sacc., from winter squash.
Caused decay of cucumber fruits.

F. discolor var. *majus* nova var., from dent corn.

F. helianthi Sacc. (sub var.) from apple fruit, potato, summer squash and sunflower.
Produced decay of carnation buds, also fruits of apple and pear. Negative results with strain from apples on potato tubers.

F. metachroum App. and Wr., from wheat.
Caused decay of apples.

F. orthoceras App. and Wr., from cucumber, pea and potato.
Positive results from inoculation of apple and cucumber fruits, negative upon carnation buds.

F. pirinum (Fries) Sacc., from apple fruit. (F XXXVIII from potato considered identical with *F. pirinum* by Lewis.)
Positive results from inoculations upon apple and pear fruits and carnation buds. Negative upon potato tubers.

F. poae (Peck) novum nomen, from dent, flint and sweet corn, fowl meadow grass, June grass, quack grass, red top, timothy and potato tuber.
Positive results from the inoculation of carnation buds with the strains from June grass, quack grass, red top, and timothy.

Negative results upon carnation buds from the strains from fowl meadow grass, dent corn and potato. Strain from sweet corn caused decay of cucumber fruit.

F. reticulatum Mont., from cucumber, winter squash and wheat.
Positive results from inoculation of carnation buds and cucumber fruits.

F. solani (Mart.) App. and Wr., from potato.

The object of the summary of the inoculation tests is simply to assemble in condensed form the more important data secured by Dr. Lewis regarding pathogenicity and align it as far as possible with the names of the different species to which Dr. Wollenweber has referred the various strains of Fusarium under consideration. Mention should be made, however, of the fact that with the possible exception of *F. conglutinans* all of the strains studied produced some decay of some varieties of apples. However, only those which gave constant and marked positive results are so credited in the summary. The details of the inoculation tests will be found on pages 239-251.

W. J. M.

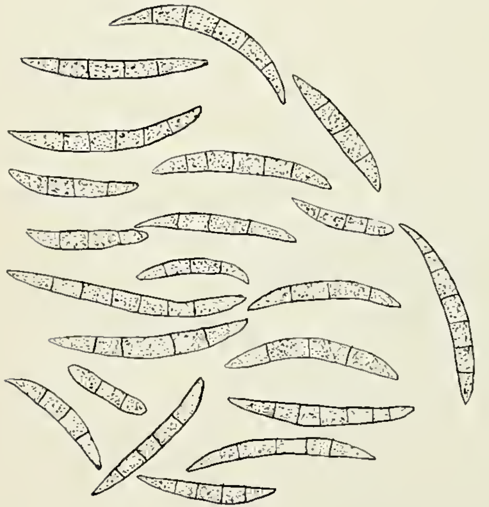

Fig. 86. Spores of F I (*F. pirinum*) from apple, from a potato agar plate culture 3 weeks old. x 480.

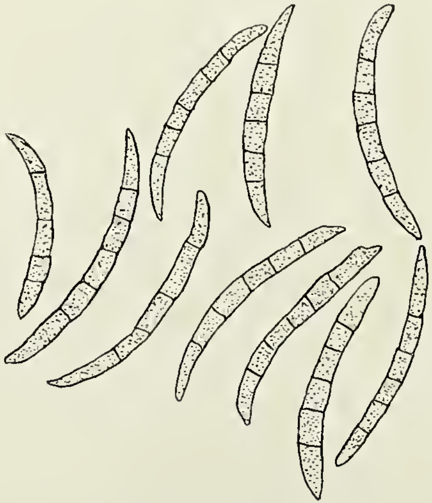

Fig. 87. Spores from a strain of F I (*F. pirinum*) isolated from Milden apple. Spores from sporodochia from a young bean-pod culture. x 480.

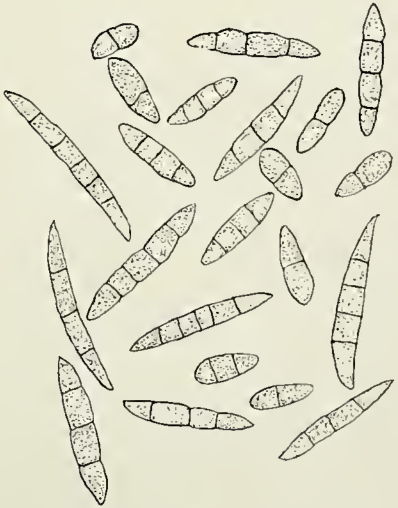

Fig. 88. Spores of F III (*F. pirinum*) from apple, from a potato agar plate culture 3 weeks old. x 480.

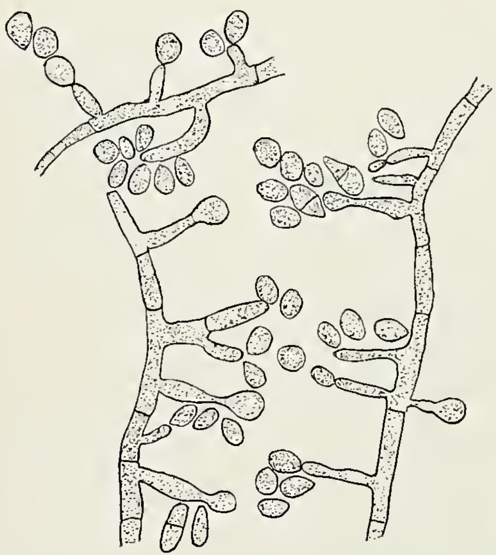

FIG. 89. Obovate spores of F IV (*F. helianthi*) from apple, showing the manner in which they are formed. From a hanging drop culture in one per cent saccharose broth. x 480.

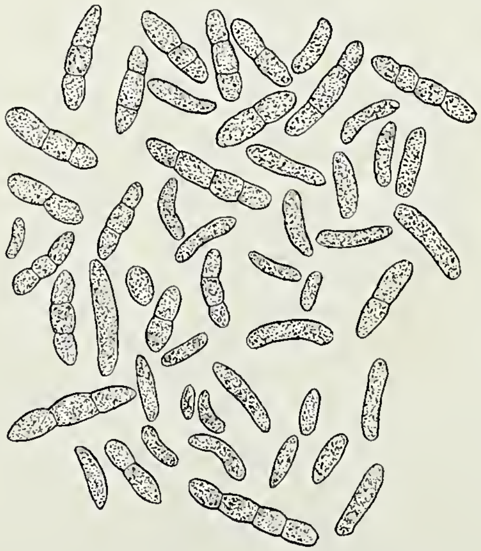

FIG. 90. Spores of F IV (*F. helianthi*) from apple, from a prune agar culture 5 days old. x 480.

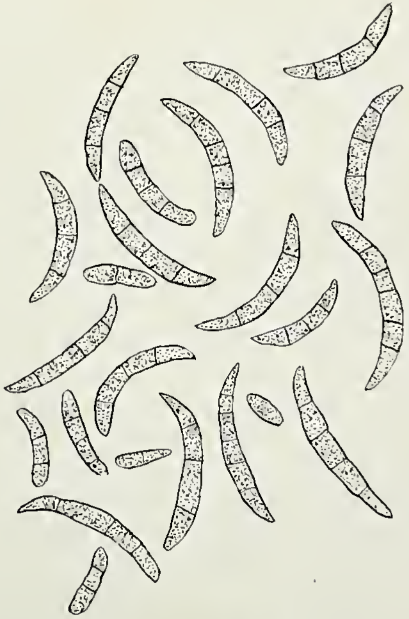

FIG. 91. Spores of F IV (*F. helianthi*) from a potato agar plate culture 3 weeks old. x 480.

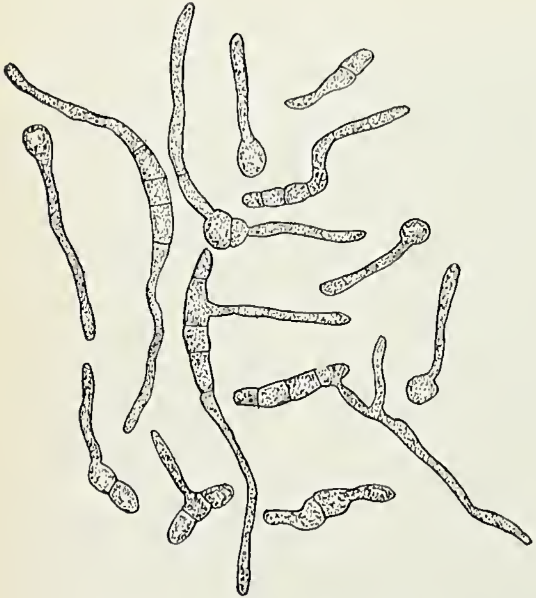

FIG. 92. Germinating spores of F II (*F. helianthi*) from apple after 4 to 6 hours in hanging drop of apple wood decoction. Obovate one-celled, pyriform 2-celled, and septate spores of the Fusarium type are shown. x 480.

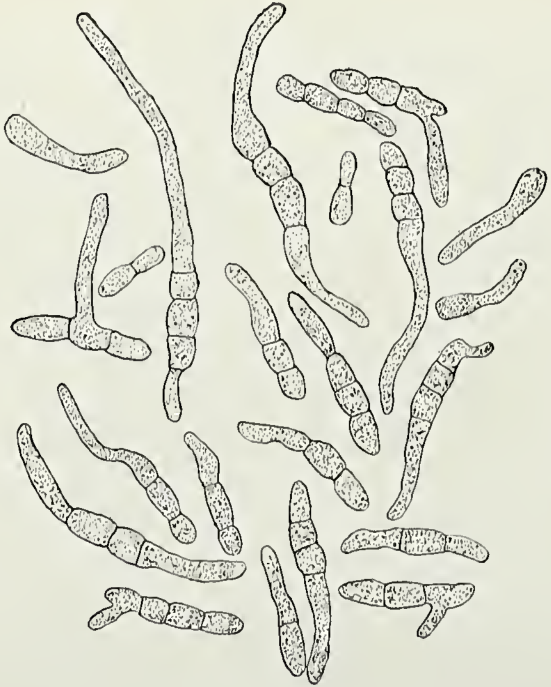

FIG. 93. Germinating spores of F IV (*F. helianthi*) after 5 to 7 hours in one per cent saccharose broth. x 480.

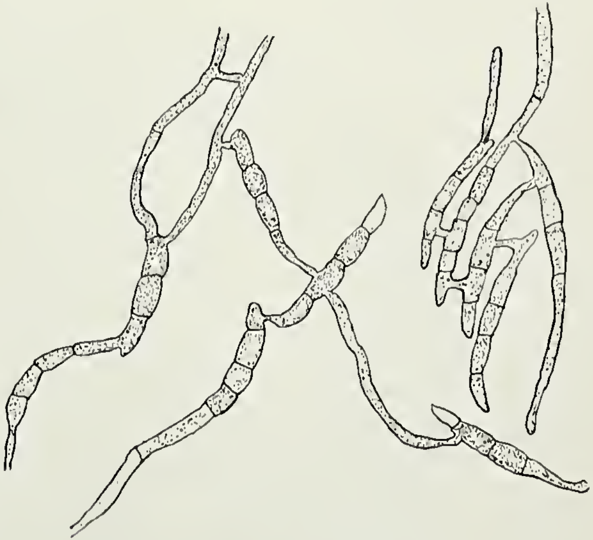

FIG. 94. Germinating spores of F I (*F. pirinum*) showing fusions after 24 hours in hanging drop of apple wood decoction. x 480.

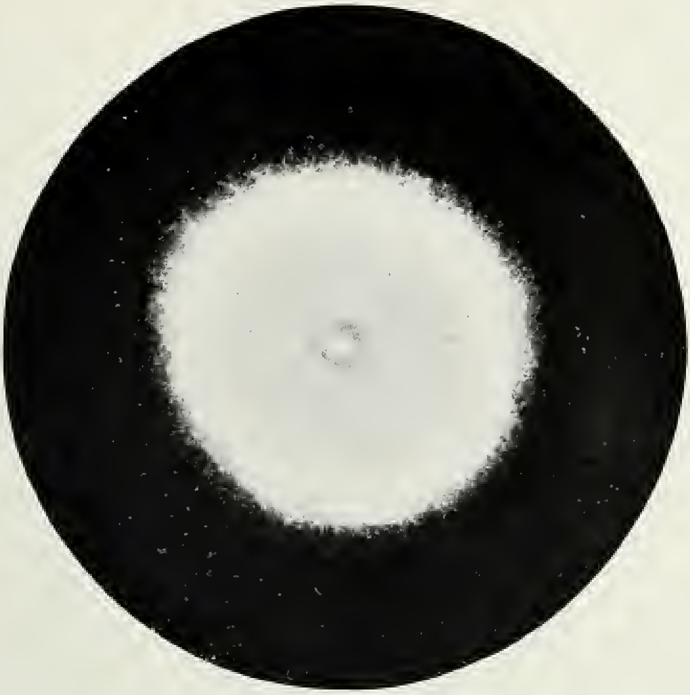

Fig. 95. F II (*F. helianthi*) from apple. Culture 4 days old on synthetic agar.

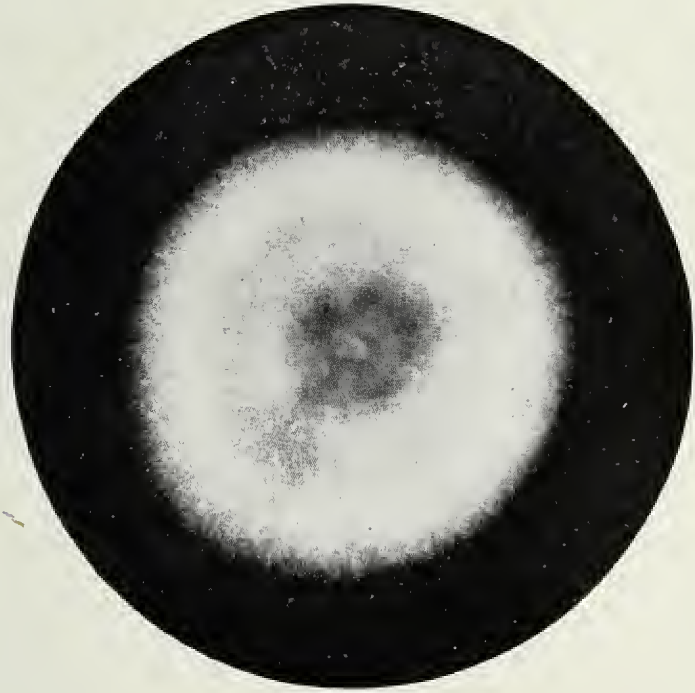

Fig. 96. F XIII (*F. helianthi*) from sunflower. Culture 4 days old on synthetic agar.

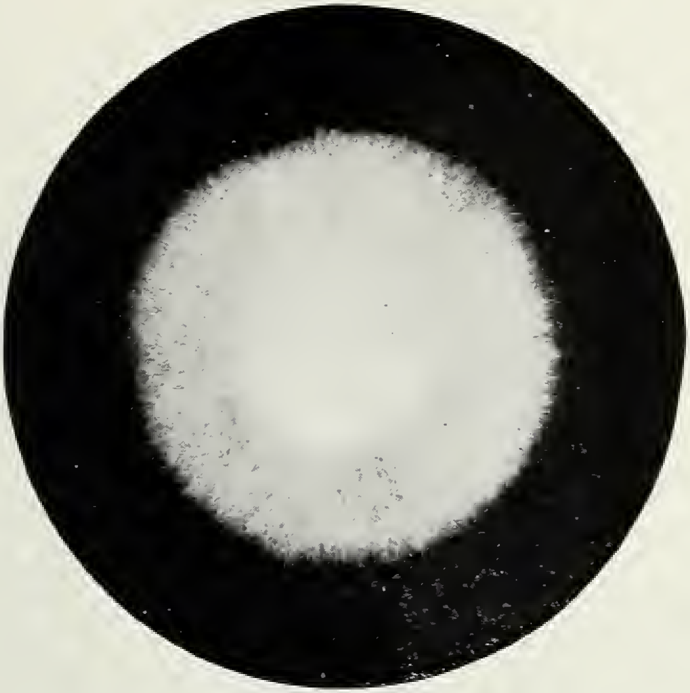

FIG. 97. F XXIV (*F. poae*) from June grass. Culture 4 days old on synthetic agar.

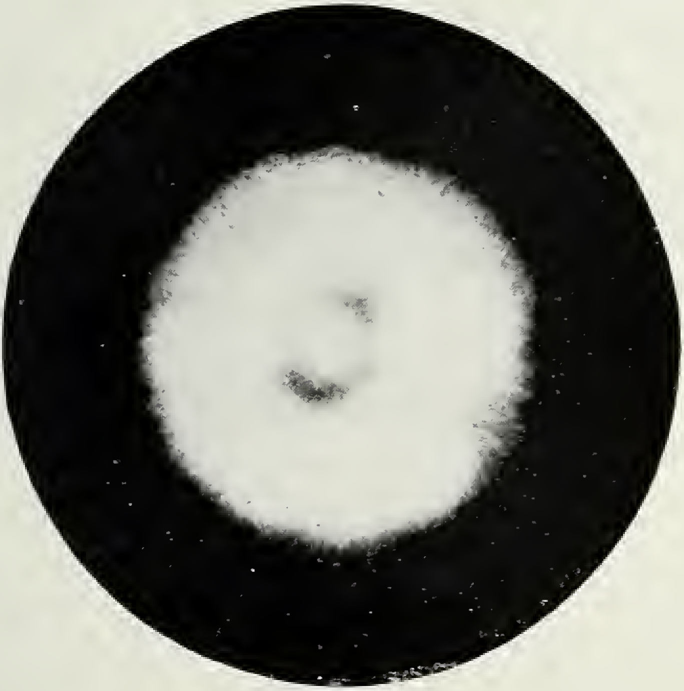

FIG. 98. F XXVI (*F. poae*) from quack grass. Culture 4 days old on synthetic agar.

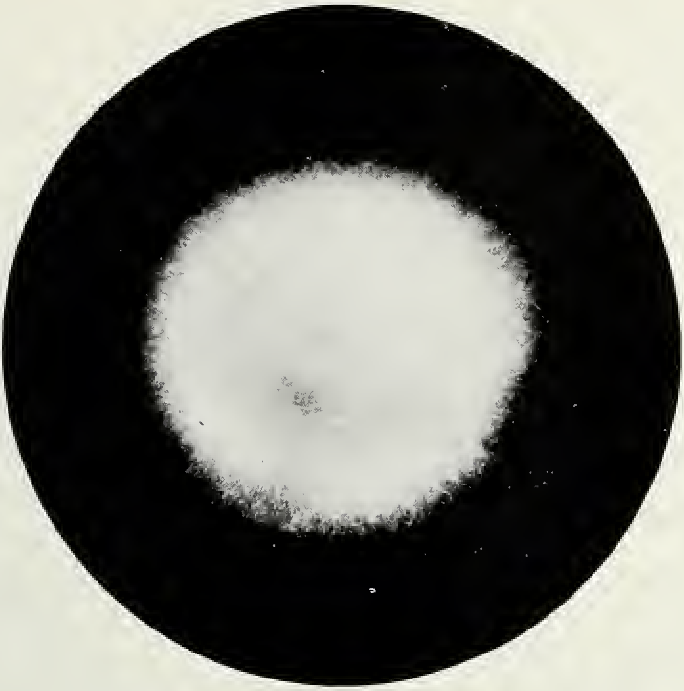

FIG. 99. F XXVIII (*F. poae*) from timothy.
Culture 4 days old, on synthetic agar.

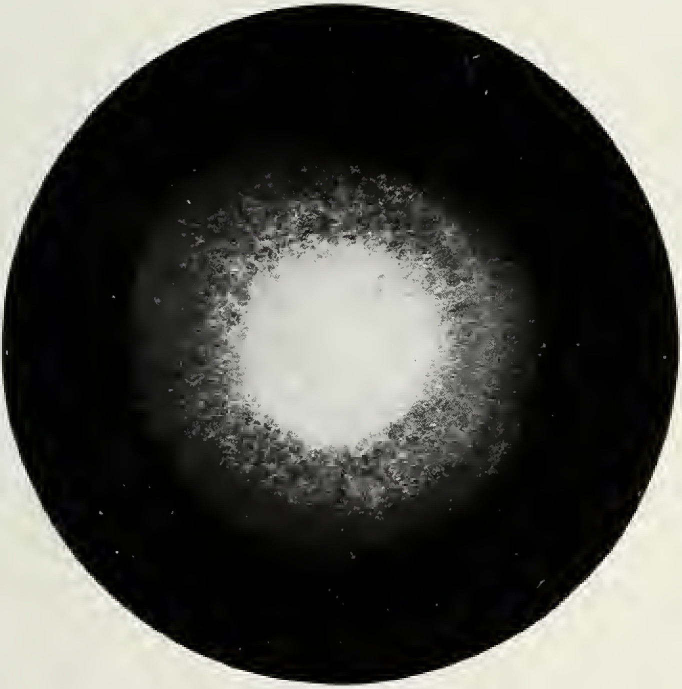

FIG. 100. F III (*F. pirinum*) from apple.
Culture one week old on synthetic agar.

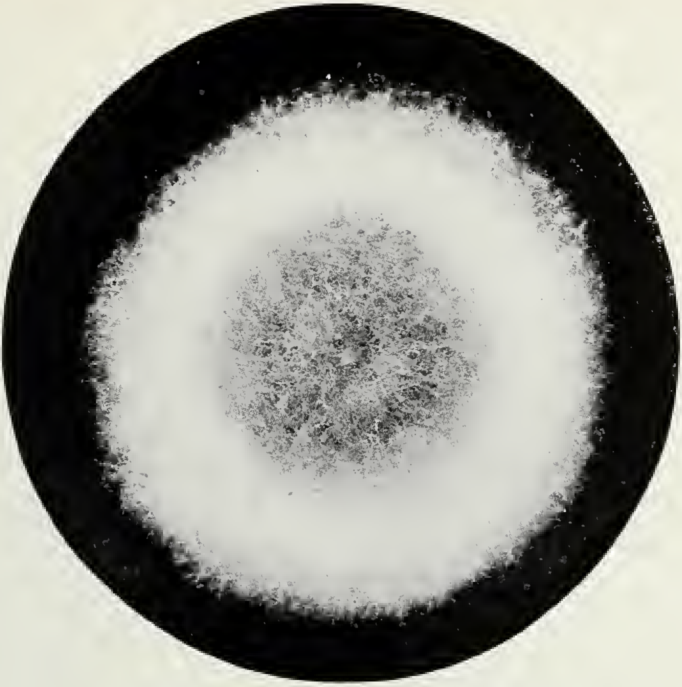

FIG. 101. F II (*F. helianthi*) from apple. Culture 5 days old on synthetic agar.

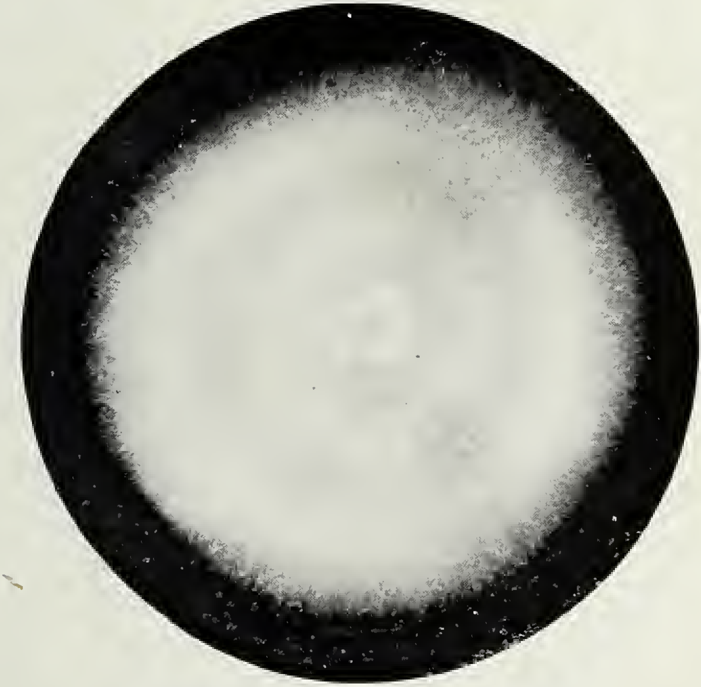

FIG. 102. F I (*F. pirinum*) from apple. Culture one week old on synthetic agar.

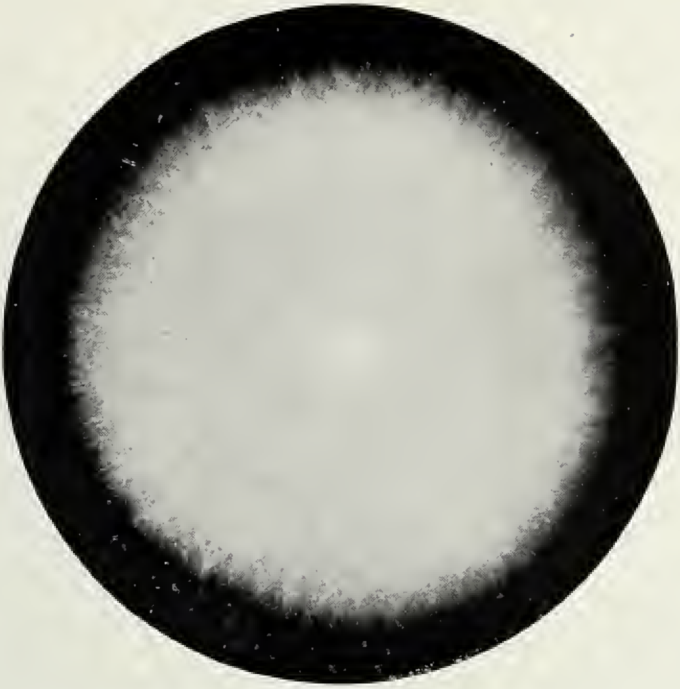

Fig. 103. F XV (*F. orthoceras*) from potato tuber from Vermont. Culture one week old on synthetic agar. This fungus was carried as *F. oxysporum*

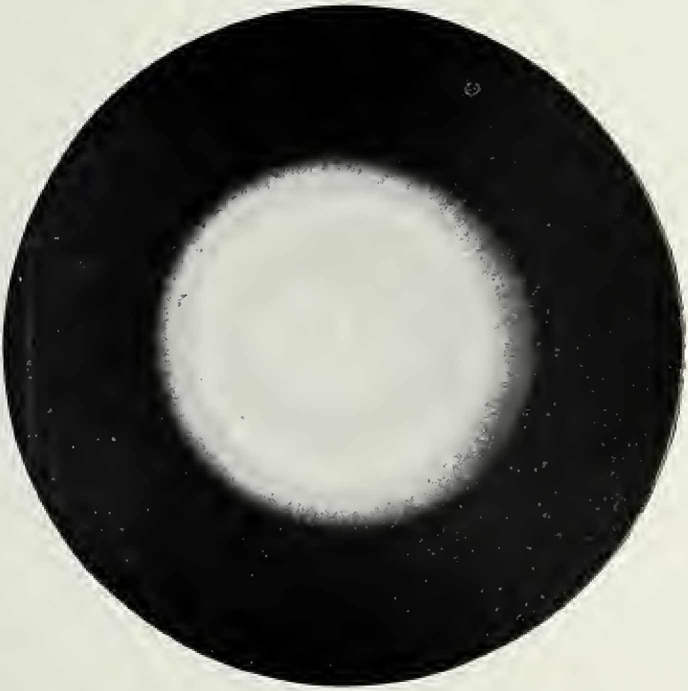

Fig. 104. F XX (*F. argillaceum*) from cucumber. Culture one week old on synthetic agar.

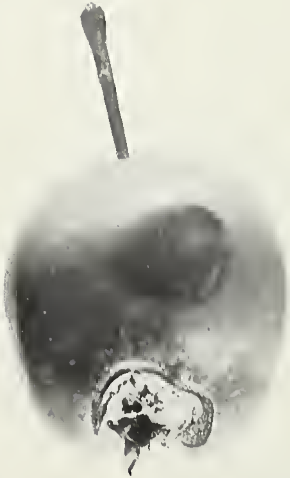

Fig. 105. Fusarium as it occurred on green apple on tree.

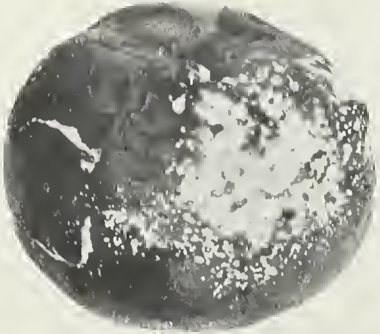

Fig. 106. F III (*F. pirinum*) on apple.

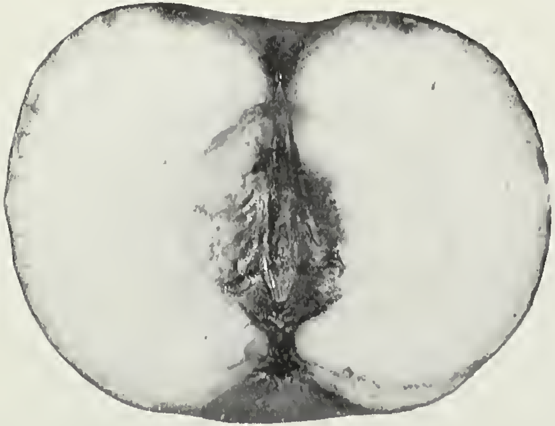

Fig. 107. Fusarium decay in core of apple.

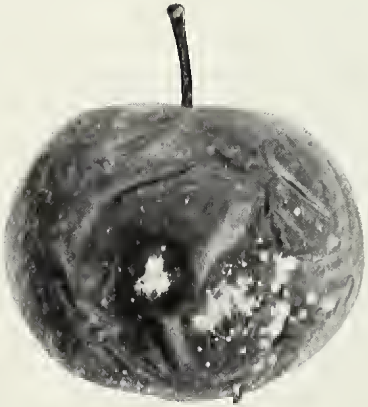

FIG. 108. Green apple 38 days after inoculation with F I (*F. pirinum*).

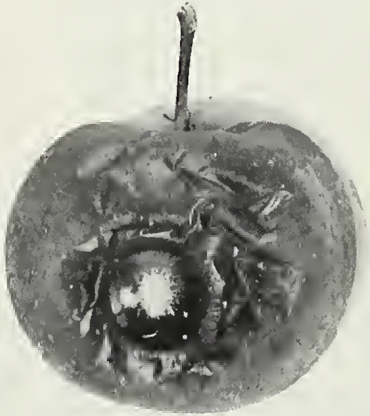

FIG. 109. Green apple 38 days after inoculation with F XII (*F. pirinum*).

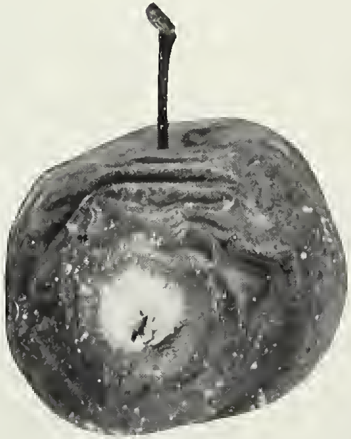

FIG. 110. Green apple 38 days after inoculation with F XV(*F. orthoceras*), which is referred to in the text as *F. oxysporum*.

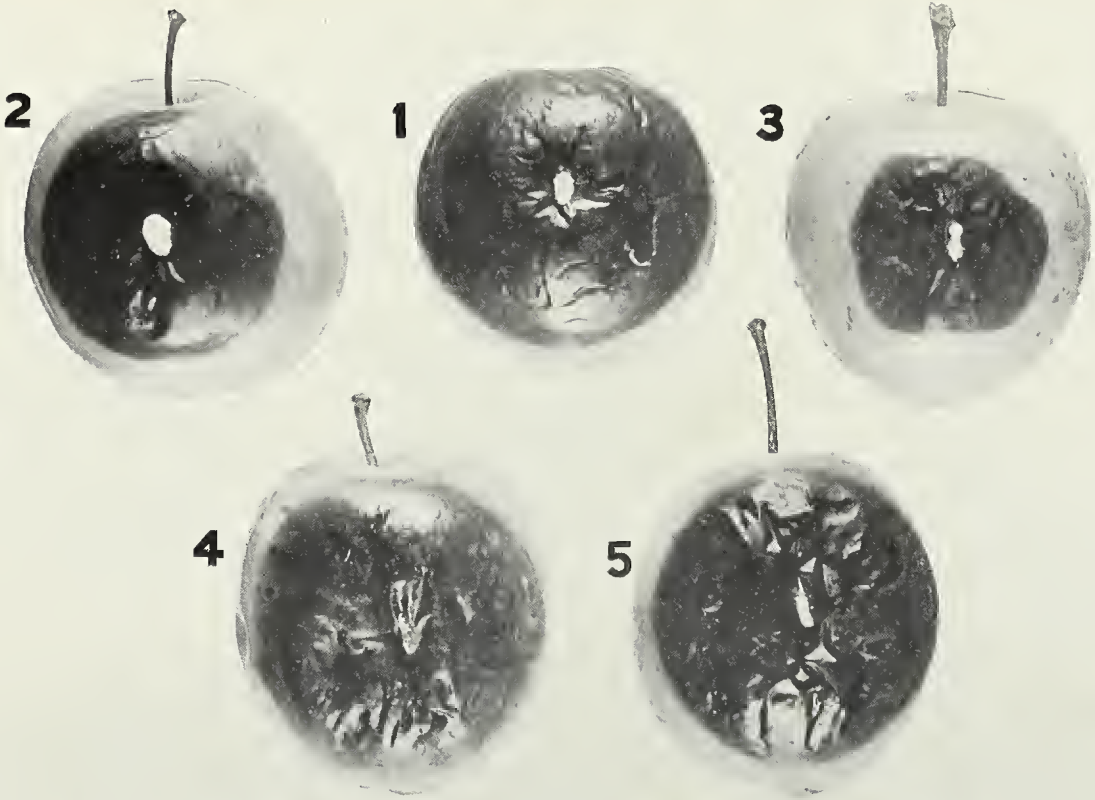

Fig. 111. Bellflower apples inoculated with Fusarium. 1 with F I, 2 with F II, 3 with F III, 4 with F IV, 5 with F XV.

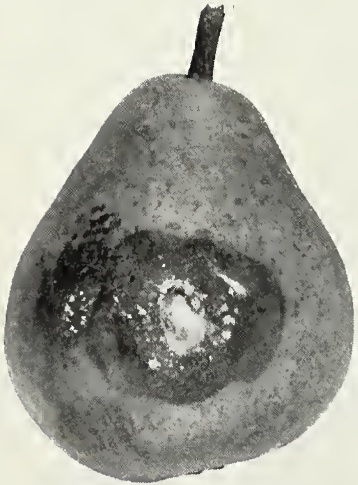

FIG. 112. Pear inoculated with F I (*F. pirinum*) from apple.

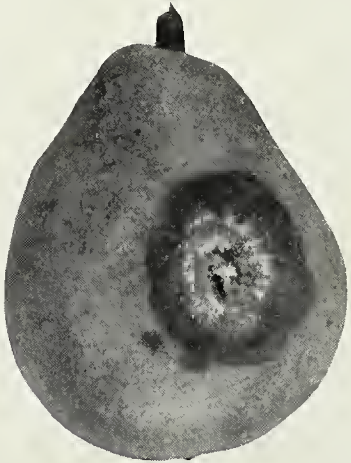

FIG. 113. Pear inoculated with F II (*F. halianthi*) from apple.

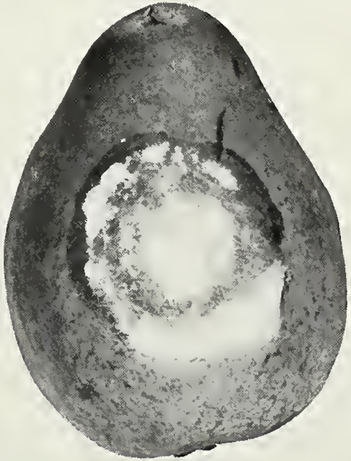

FIG. 114. Pear inoculated with culture received from Osterwalder as *F. putrefaciens* (*F. pirinum*, according to Wollenweber).

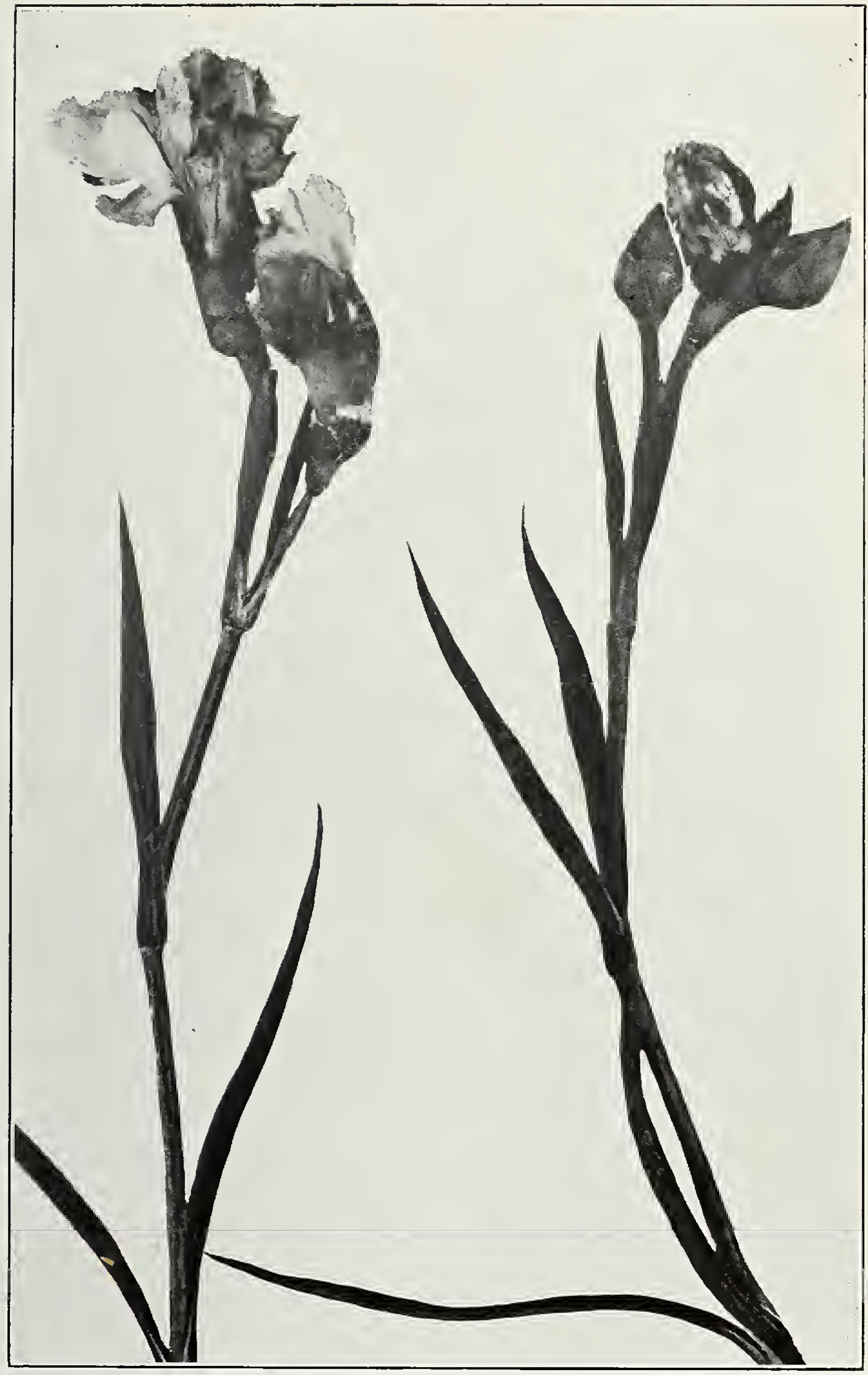

FIG. 115. Carnation bud-rot produced by inoculation with F II (*F. helianthi*) from apple.

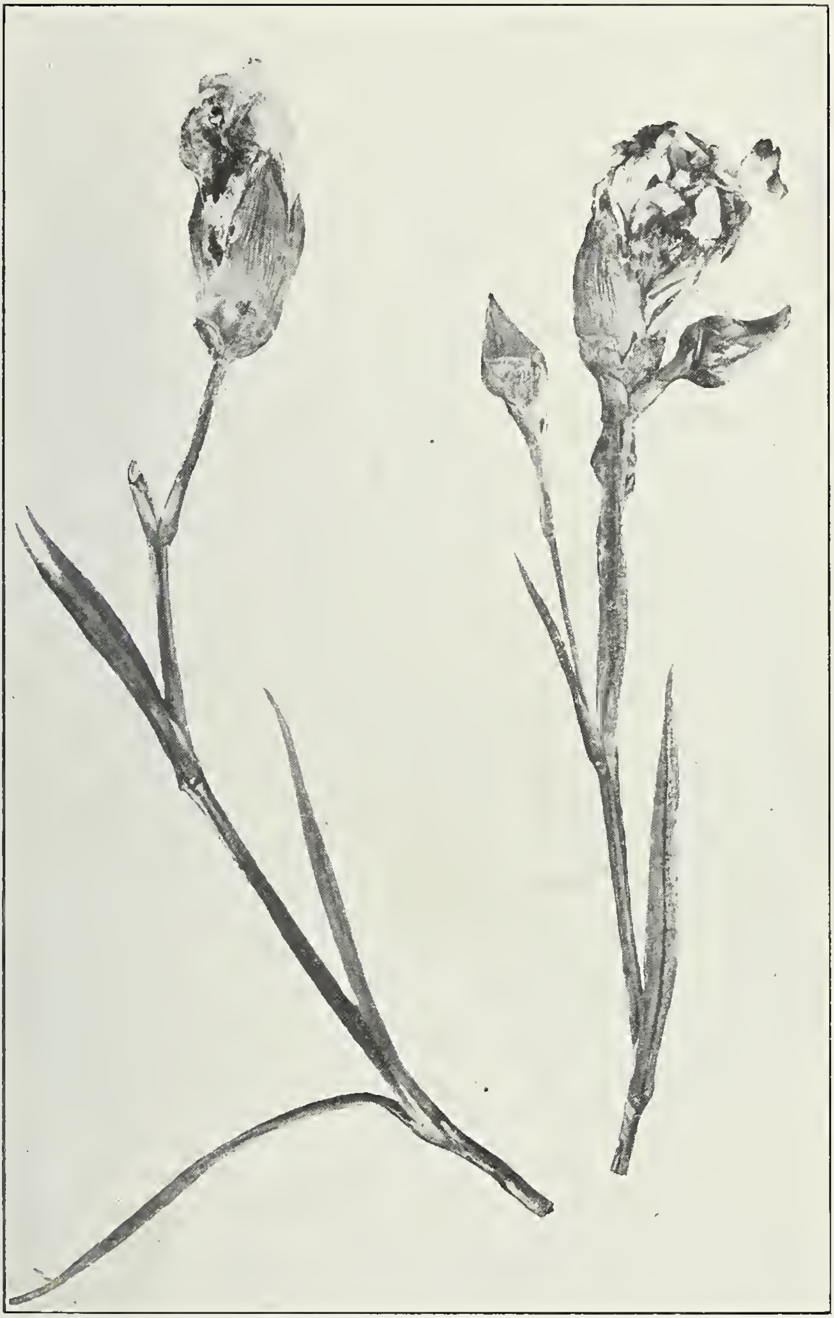

FIG. 116. Carnation bud-rot produced by inoculation with culture received as *F. putrefaciens*. (*F. pirinum*, according to Wollenweber).

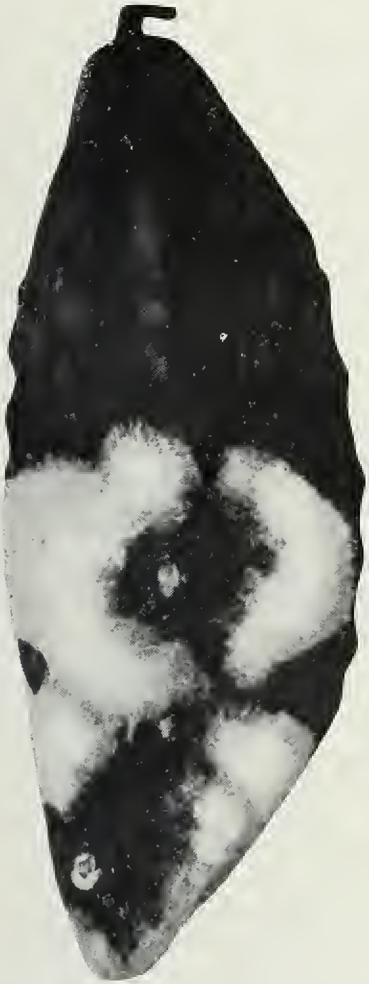

FIG. 117. Decay of cucumber produced by inoculation with F II (*F. helianthi*) from apple.

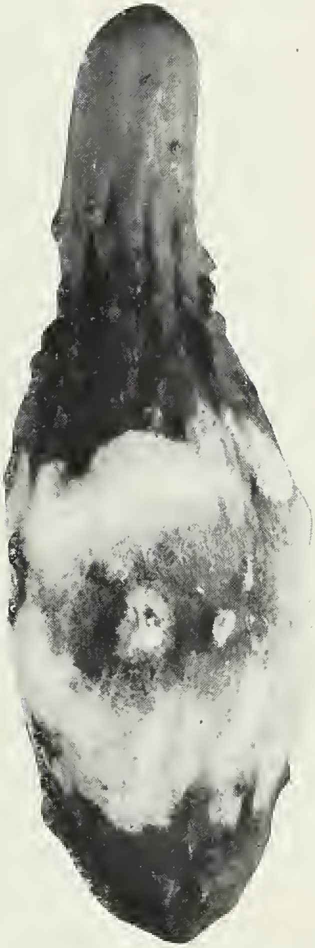

FIG. 118. Cucumber inoculated with F XIII (*F. helianthi*) from sunflower.